SEE
FOLLOWING
NOTE

VOIR
NOTE
CI-APRÈS

PARTS OF THE ORIGINAL DOCUMENT ARE OF POOR REPRODUCTIVE QUALITY.

MICROMEDIA LIMITED HAS ATTEMPTED TO PRODUCE THE BEST POSSIBLE COPY.

CERTAINES PARTIES DU DOCUMENT ORIGINAL SONT DE PIÈTRE QUALITÈ DE REPRODUCTION.

MICROMEDIA LTEE A ESSAYEE DE PROCURER LE MEILLEUR EXEMPLAIRE POSSIBLE.

NO
PAPER
RIGHTS

REIMPRESSION
INTERDITE

TANK TESTING OF SKIMMERS WITH WAXY AND VISCOUS OILS

Prepared by

CANADIAN PETROLEUM ASSOCIATION

and

CANADIAN COAST GUARD

OCTOBER, 1989

S.L. ROSS ENVIRONMENTAL RESEARCH LIMITED
OTTAWA, CANADA
CANADIAN PETROLEUM ASSOCIATION

TANK TESTING OF SKIMMERS WITH WAXY AND VISCOUS OILS

Prepared by

CANADIAN PETROLEUM ASSOCIATION

and

CANADIAN COAST GUARD

OCTOBER, 1989

S.L. ROSS ENVIRONMENTAL RESEARCH LIMITED
OTTAWA, CANADA

92-02804/

SUMMARY

A series of tests of four offshore skimmers (Framo ACW–400, GT–185, Walosep W–2, Heavy Oil Skimmer) was conducted in a large wave basin (120 m long x 60 m wide x 3 m deep) during the fall of 1988. Each skimmer was tested with each of three oils: IPL Sweet, a conventional crude oil; Terra Nova C–09, a waxy crude oil from the Grand Banks; and Bunker C. Each test involved four to six hours of skimming during which the recovered oil was recycled to the basin thus allowing evaluation of the skimmers with weathered and emulsified oils. Part of each test was conducted in waves having a 4 s period and heights varying from 0.4 –0.8 m. Near the end of selected tests, the additive Elastol was applied to the oil and its effect on recovery parameters evaluated.

Figure S1 summarizes the general trend in the corrected recovery rate (i.e., the fluid recovery rate less the water entrainment rate) as a function of oil viscosity for the Framo ACW–400, GT–185 and Walosep W–2 skimmers; the experimental Heavy Oil Skimmer failed to recover oil at significant rates without the addition of Elastol to the oils. It should be noted that the Walosep W–2 could not be operated at full capacity due to limitations of the hydraulic power pack.

Table S1 gives the optimum corrected recovery rates and the percentage of oil or emulsion in the recovered fluid measured for each of the oils. All the optimum results were obtained in calm conditions. In general, waves had no effect on the performance of the Walosep W–2, had little effect on the performance of the GT–185 and greatly reduced the performance of the Framo ACW–400.

Unfortunately, despite the fact that the temperatures during the tests were not low enough to cause the waxy oil to gel completely, the tests showed that the GT–185, Walosep W–2 and Framo ACW–400 should be able to recover slicks of relatively fresh waxy oils and their emulsions at peak summer water temperatures on the Grand Banks (12°C). The test results showed that corrected recovery rates under these conditions would be 30 – 40% less than for a conventional crude with the Framo ACW–400 and about the same as the recovery rates for a conventional crude with the GT–185 and Walosep W–2 skimmers. More water was entrained by the Framo ACW–400

FIGURE S1

RECOVERY RATE COMPARISON

Framo ACW-400, GT-185 and Walosep W-2

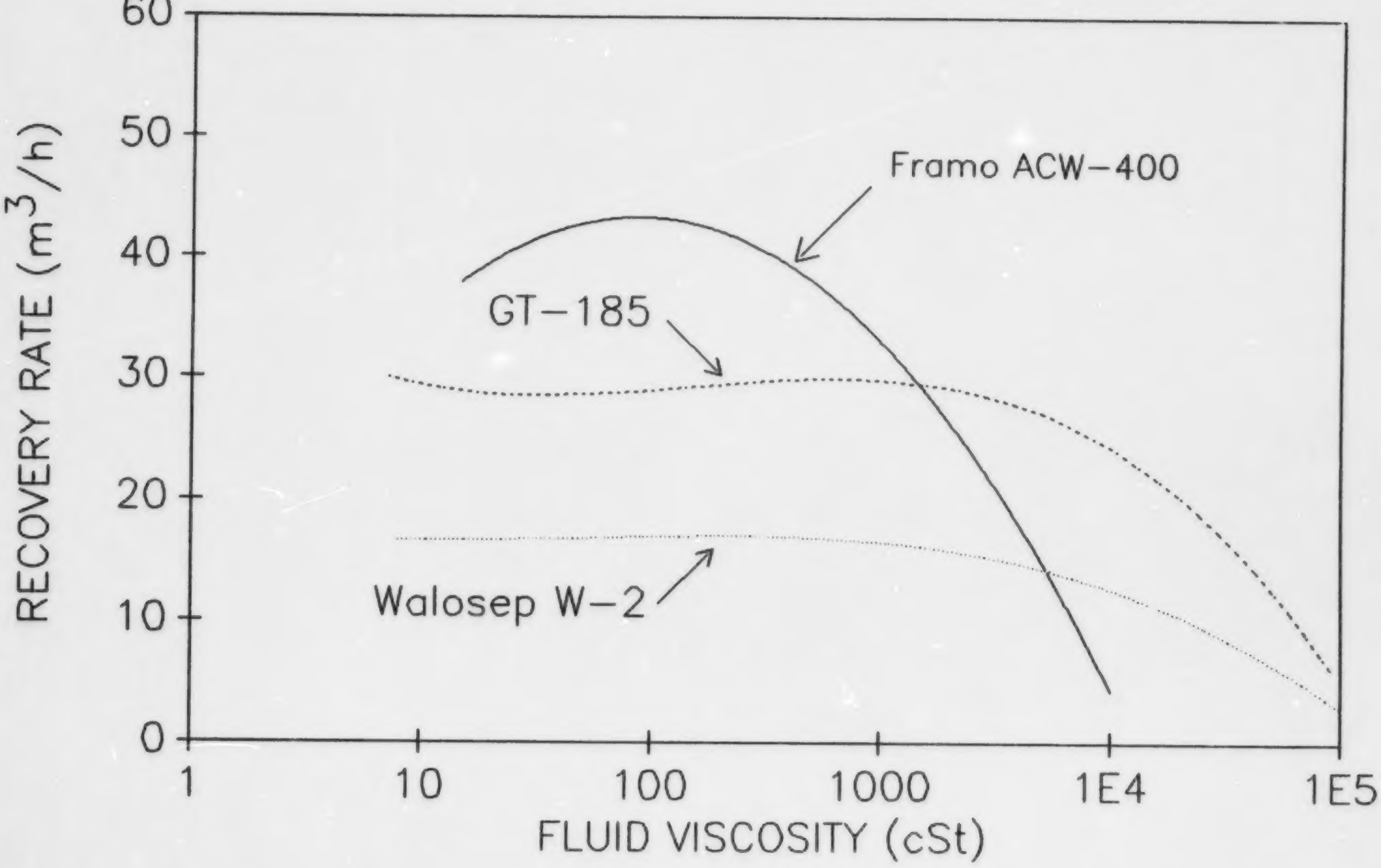


TABLE S1

OPTIMUM TEST RESULTS

Skimmer	IPL	Terra Nova	Bunker C	
	Sweet Crude	C–09 Crude	10,000 cSt	100,000 cSt
FRAMO ACW–400				
Corrected Recovery Rate	53 m^3/hr	53 m^3/hr	10 m^3/hr	-----
Percent oil/emulsion in recovered fluid	98%	93%	88%	-----
GT–185				
Corrected Recovery Rate	30 m^3/hr	30 m^3/hr	24 m^3/hr	15 m^3/hr
Percent oil/emulsion in recovered fluid	99+%	99+%	99+%	50%
WALOSEP W–2				
Corected Recovery Rate	16 m^3/hr	15 m^3/hr	-----	5 m^3/hr
Percent oil/emulsion in recovered fluid	99+%	99+%	-----	47%
HEAVY OIL SKIMMER				
Corrected Recovery Rate	0 (12 m^3/hr)+	2 m^3/hr (15 m^3/hr)+	-----	0 (5 m^3/hr)+
Percent oil/emulsion in recovered fluid	-- (99+%)+	99+% (99+%)+	-----	---

+ with addition of Elastol

and GT–185 skimmers when skimming waxy oil compared to conventional oil, but this was not the case for the Walosep W–2 skimmer. Based on visual observations of the skimmers the Walosep W–2 may be the best one for recovering pieces of gelled oil at colder temperatures on the Grand Banks.

The addition of Elastol to test oils and emulsions improved the corrected recovery rates of the Walosep W–2 by about 15% and had no effect on its water entrainment rate. For the Framo ACW–400, Elastol addition had no effect on the corrected recovery rate but increased its water entrainment rate. Elastol reduced the recovery rate of the GT–185 by 25 – 35% and increased its water entrainment rate. The addition of Elastol also had several negative effects on subsequent downstream operations, including difficulty in pumping treated oil and the level of effort required to clean treated oil off equipment.

ACKNOWLEDGEMENTS

The authors of this report were Ian Buist and Stephen Potter of S.L. Ross Environmental Research Limited. The authors would like to acknowledge the following for their invaluable assistance in the tests:

- Mr. E. Gauthier, Captain M. Greenham and the staff of Canadian Coast Guard Emergencies – Headquarters in Ottawa
- Mr. Jim Swiss and Mr. Ian Scott of the Canadian Petroleum Association
- Mr. W. Ryan, Mr. W. Halley and the staff of Canadian Coast Guard Emergencies – Newfoundland Region in St. John's
- Mr. R. Whitehorn, Mr. R. Amel and the staff of Canadian Coast Guard Emergencies – Central Region in Prescott
- Mr. G. Warbanski, Mr. E. Tuck and the staff of East Coast Spill Response Incorporated in St. John's
- Mr. A. Shah and the staff of ASI in Long Beach, CA
- Ms. R. Denison of the National Research Council, Institute for Marine Dynamics in Ottawa
- Mr. D. Taylor of General Technology Applications Inc. of Manassas, VA

Funding for this study was provided by the Canadian Petroleum Association, the Canadian Coast Guard, Eastcoast Spill Response Incorporated, Petro Canada, Husky Oil and Mobil Oil Canada.

TABLE OF CONTENTS

PAGE

1.0 INTRODUCTION 1
  1.1 Study Rationale and Background 1
  1.2 Objective 4
  1.3 Goals 4

2.0 EQUIPMENT AND METHODS 6
  2.1 Test Tank 6
  2.2 The Skimmers 9
  2.3 The Oils 12
  2.4 Site Layout and Ancillary Equipment 13
  2.5 Analytical Equipment and Techniques 18
    2.5.1 Flow Measurement and Properties 18
    2.5.2 Recovered Fluid Analysis 18
  2.6 Skimmer Testing Procedures 21
  2.7 Calculation of Skimmer Performance Data 23

3.0 RESULTS AND DISCUSSION 25
  3.1 General 25
  3.2 Skimmer Tests 28
    3.2.1 Framo ACW–400 28
      3.2.1.1 Test With IPL Sweet Crude 28
      3.2.1.2 Test with Bunker C 33
      3.2.1.3 Test with Terra Nova C–09 36
      3.2.1.4 Comparison 42
    3.2.2 GT–185 44
      3.2.2.1 Test with IPL Sweet Crude 44
      3.2.2.2 Test with Bunker C 48
      3.2.2.3 Test with Terra Nova C–09 Crude 50
      3.2.2.4 Comparison 54
    3.2.3 Heavy Oil Skimmer 56

TABLE OF CONTENTS

PAGE

3.2.3.1 Test with IPL Sweet Crude 56
3.2.3.2 Test with Bunker C 59
3.2.3.3 Test with Terra Nova 62
3.2.3.4 Comparison 64
3.2.4 Walosep W–2 65
3.2.4.1 Test with IPL Sweet 65
3.2.4.2 Test with Bunker C 68
3.2.4.3 Test with Terra Nova C–09 Crude 72
3.2.4.4 Comparison 75
3.3 Summary 77
3.3.1 Recovery Rate and Oil Content Factor 77
3.3.2 Effects of Waxy Oil 80
3.3.3 Effect of Elastol Treatment 81

4.0 CONCLUSIONS AND RECOMMENDATIONS 83
4.1 Conclusions 83
4.2 Recommendations 84

5.0 REFERENCES 86

APPENDIX I: SKIMMER SPECIFICATIONS
APPENDIX II: FLOWMETER SPECIFICATIONS AND CALIBRATION
APPENDIX III: ANALYTICAL PROCEDURES AND CALCULATIONS
APPENDIX IV: SKIMMER RAW DATA AND FIELD NOTES

LIST OF FIGURES

FIGURE		PAGE
1:	Test site – NRC Outdoor Ship Manoeuvring Basin and Building M–42	7
2:	Wave tank (looking towards wave beach)	7
3:	Boom layout in wave tank	8
4:	The Walosep W–2 skimmer	10
5:	The Framo ACW–400 skimmer head	10
6:	The GT–185 skimmer	11
7:	The Heavy Oil Skimmer	11
8:	Equipment layout	14
9:	Piping layout	15
10:	Aerial view of site	16
11:	Spill plate in enclosed test area	17
12:	Steel test section for flow measurement and sampling	19
13:	Application of slurried Elastol to oil by hose	22
14:	Mixing of Elastol with oil using a fire pump	22
15:	Terra Nova C–09 test slick gelled after overnight exposure	27
16:	Variation in wave height with time	29
17:	ACW–400 with IPL Sweet	30
18:	Framo ACW–400 operating in IPL Sweet crude oil	31
19:	Framo ACW–400 skimmer pushing oil away from discs in waves	34
20:	ACW–400 with Bunker C	35
21:	ACW–400 with Terra Nova Crude	37
22:	Appearance of Terra Nova C–09 test slick prior to commencing Framo ACW–400 test	38
23:	Channeling of recycled Terra Nova C–09 crude oil from spill plate to skimmer	40
24:	Recovery rate vs. viscosity: Framo ACW–400	43
25:	GT–185 with IPL	45
26:	GT–185 with Light Oil Adapter in place	46

LIST OF FIGURES Cont.

FIGURE **PAGE**

27: GT–185 with Bunker C 49

28: GT–185 with Light Oil Adapter removed 51

29: GT–185 with Terra Nova crude 52

30: Recovery rate vs. viscosity: GT–185 55

31: Heavy oil skimmer with IPL 57

32: Heavy oil skimmer operating in IPL sweet crude 58

33: Heavy oil skimmer with Bunker C 60

34: Heavy oil skimmer operating in Bunker C in upward rotation mode 61

35: Heavy oil skimmer with Terra Nova crude 63

36: Walosep with IPL 66

37: Walosep W–2 skimmer operating in IPL Sweet crude oil 67

38: Walosep W–2 with Bunker C 69

39: Walosep W–2 operating in emulsified Bunker C 70

40: Walosep with Terra Nova crude 73

41: Walosep W–2 in Terra Nova C–09 crude oil 74

42: Recovery rate vs. viscosity: Walosep W–2 76

43: Recovery rate comparison: Framo ACW–400, GT–185 and Walosep W–2 78

LIST OF TABLES

TABLE		PAGE
1	Properties of test oils (fresh)	12
2	Initial test conditions	26

1.0 INTRODUCTION

This study involved the testing of several offshore skimmers in a large wave basin to evaluate and compare their effectiveness in recovering spills of conventional and waxy crude oils (and their emulsions) and a viscous residual fuel oil. The additive Elastol was also evaluated for its potential to improve skimmer efficiency.

Section 2.0 of this report describes the basin, skimmers, analytical equipment and techniques and the oils used in the tests. The test methodology is documented as well. Section 3.0 contains the results of the individual tests and a discussion thereof. Section 4.0 presents the conclusions and recommendations arising from the study. Equipment specifications, calibration curves and raw data may be found in the Appendices.

1.1 Study Rationale and Background

Major oil spills off the East Coast of Canada are increasingly likely to involve relatively viscous oils, oils that could pose serious difficulties to currently available spill recovery systems.

The process of evaluating spill countermeasures to deal with waxy and viscous crude oils was begun four years ago by Mobil Oil Canada Ltd. and its partners in their study of Hibernia oils for the Hibernia Environmental Impact Statement (S.L. Ross 1984). Petro–Canada conducted similar studies on the properties of oils from the Terra Nova field (S.L. Ross 1985a). This was followed by two Environmental Studies Research Fund (ESRF) projects: the first was a paper evaluation of the feasibility of countermeasures for spills of waxy, viscous oils (S.L. Ross and Hatfield 1986), and the second was a major laboratory study of the fate and behaviour of waxy crude oil spills (S.L. Ross and DMER 1988). Most recently, a large trial of offshore spill containment and recovery equipment was carried out near St. John's, Newfoundland; the oil used in these tests was selected for its resemblance to the waxy oils recently discovered in the Grand Banks (S.L. Ross 1987).

The early industry EIS studies identified the unique spill properties of waxy oils, most notably high pour point, unusual rheology, low evaporation and slow natural dispersion rates. The low effectiveness of chemical dispersants on these oils was also identified (S.L. Ross 1984).

Follow-up work to these studies showed that as waxy oils evaporate they form a skin on their surface, and that this skin dramatically reduces the oil's adherence to oleophilic surfaces (S.L. Ross 1985b).

The first ESRF study (S.L. Ross and Hatfield 1986) of waxy, viscous crude oil spills focused on the likely feasibility and applicability of countermeasures for these oils. Based on experience with various generic recovery techniques, published test data using conventional oils and limited small-scale testing, the authors concluded that the unique spill behaviour of waxy crude oils would pose problems for conventional countermeasures. Specifically it was felt that the tendency of waxy oils to form discrete, semi-solid mats, blobs and droplets that do not adhere well nor recoalesce when spilled would render recovery ineffective with most skimmers that employ oleophilic or weir principles. This implied that the majority of offshore skimmers in Canada would not be very useful in a spill of waxy oil. Testing of these skimmers to confirm their capabilities and of two relatively new skimmer designs (the Walosep induced flow skimmer and the Seawolf toothed disc skimmer) was recommended. In particular the Walosep, with its induced flow skimming principle, internal oil/water separating and its seeming insensitivity to oil form and "stickiness", seemed to offer a solution to the problems associated with waxy oil recovery.

The second ESRF (S.L. Ross and DMER 1988) study of waxy oils encompassed an in-depth laboratory and mid-scale investigation of the behaviour and fate of waxy oil spills. A small component of this study involved mid-scale tank testing of potential countermeasures, and included chemical dispersion, containment with booms and nets, adherence of oil to oleophilic materials and in-situ burning.

The previous observations of unique spill behaviour were confirmed: blowouts involving very waxy oils could produce streams of non-sticky, non-recoalescing droplets on the water surface and batch spills of waxy oils could spread, evaporate and naturally disperse very slowly resulting in discrete mats and blobs of emulsified oil on the sea surface. Regardless of spill source, these oil pieces are expected to survive for exceptionally long times even in rough seas and retain their lighter ends (the more toxic components of an oil) for long periods.

The countermeasures studies indicated that chemical dispersants were completely ineffective on spills of these oils. Although the oil could be boomed with conventional barriers, the oil pieces did not coalesce to form a continuous slick when contained. Netting contained the oil forms but extrusion pressures were very low and it is unlikely that the oil could be recovered from the water with nets without significant losses. Adherence of the oil forms to oleophilic materials was poor at temperatures below the oil's pour point. In–situ burning techniques proved to be as effective on contained oil as for conventional oils.

The most recent study of countermeasures for waxy oil spills entailed a major field trial of Coast Guard offshore spill containment and recovery equipment some 25 miles east of St. John's in September 1987 (S.L. Ross 1987). The test oil was a North Sea crude doped with a small amount of wax to raise its pour point to 6°C and emulate the properties of a moderately waxy crude. The two offshore booms tested, the RO–BOOM and Vikoma Ocean Pack, proved equally capable of containing the oil and its emulsion. Unfortunately, due to operational difficulties, mechanical failures and the addition of the skimming enhancement additive Elastol between skimming tests, the stated objective of these trials (evaluating the skimmers' performance with waxy oils) was not fully met.

The Framo ACW–400 skimmer was tested in emulsion prior to the addition of Elastol, and it recovered fluid at an average rate of 39 m^3/hr over a 23 minute period with an oil recovery efficiency (percent of oil in recovered fluid) of 35% (hence an oil recovery rate 14 m^3/h). The GT–185 weir skimmer recovered Elastol–treated emulsion at an average rate of 19 m^3/hr over a period of 29 minutes with an oil recovery efficiency of 46% (9 m^3/hr). The experimental Heavy Oil Skimmer recovered Elastol–treated emulsion at an average rate of 11 m^3/hr over a period of six minutes with an oil recovery efficiency in the 35% range. The Heavy Oil Skimmer was the only one of the three tested that was operated both before and after Elastol addition. Elastol treatment of the oil enhanced the performance of this skimmer.

In summary, the offshore tests were valuable but inadequate as an evaluation of the skimmers' true abilities to recover waxy and viscous oils offshore.

The Canadian Coast Guard has, on a continuous basis, researched and developed equipment for the recovery of spills of viscous fuel oils (e.g., Gauthier 1986) such as Bunker C, which represents about half of the marine spills in Canada (S.L. Ross 1988a). A recently developed skimmer head, the Heavy Oil Skimmer, was designed to recover Bunker C in higher sea states than was previously possible using the "Slicklicker" (Canpolar 1986).

Although much had been learned about the fate and behaviour of waxy and viscous oil spills and countermeasures for these oils, additional tank testing was required to evaluate the potential application of various skimmers for the recovery of these oils offshore.

1.2 Objective

The objective of this study was to evaluate the performance of four offshore skimmers with a range of waxy, viscous oils at temperatures representative of conditions on the Grand Banks. A secondary objective was to evaluate the efficacy of using Elastol to enhance offshore spill recovery.

1.3 Goal

More specifically, the goal was to measure the fluid recovery rate and oil recovery efficiency of the following skimmers:

- the Framo ACW–400 (manufactured by Frank Mohn A/S);
- the Heavy Oil Skimmer (manufactured by Canpolar);
- the GT–185 (manufactured by Pharos Marine); and
- the Walosep W–2 (manufactured by Mattsonprodukter).

The work was to be performed in a large wave tank at 10°C with:

- a conventional crude oil (for comparison);
- a waxy crude oil (with a pour point well above ambient temperatures); and
- Bunker C with a density in the range of 0.95 – 0.98 at 10°C.

Each skimmer trial was to involve four to six hours continuous operation with each oil to permit a thorough evaluation of both recovery parameters and operational reliability. A one to two hour evaluation of Elastol treatment of the slick was to be included at the end of each test.

2.0 EQUIPMENT AND METHODS

2.1 Test Tank

The Outdoor Ship Manoeuvring Basin at the Montreal Road facility of the National Research Council of Canada in Ottawa was used for the tests. This tank (Figures 1 and 2) was ideal for the study, being large (120 m x 60 m x 3 m deep) and fitted with a wave generator capable of generating regular waves 0.5 – 0.75 m in height. Facilities at the site included a workshop, control tower, wavemaker, wave beach and flood–lighting for night work.

Although there is no facility for creating currents in the tank, this was not felt to be a disadvantage; in fact, the use of tow bridges to create relative water velocities severely constrains available test times to that required to traverse the tank.

Containment booms were used to thicken the oils to thicknesses representative of offshore recovery operations (5–10 cm). (Figure 3 shows the placement of the various booms). The test area was formed by a 36" boom in a square configuration 7.5 m on a side containing an area of about 60 m^2. Subsequently, a home–made silt boom, consisting of two 15 m x 4 m plastic tarpaulins suspended from 18" boom was used to line the test area boom because of the Framo ACW–400 skimmers' propensity to push oil under the booms. The perimeter of the tank was lined by containment boom to minimize oiling of the tank walls. A 36–inch boom was deployed inside the perimeter boom as a secondary containment system. A sorbent boom was placed across the tank in front of the wave beach to absorb any sheens escaping from the containment booms.

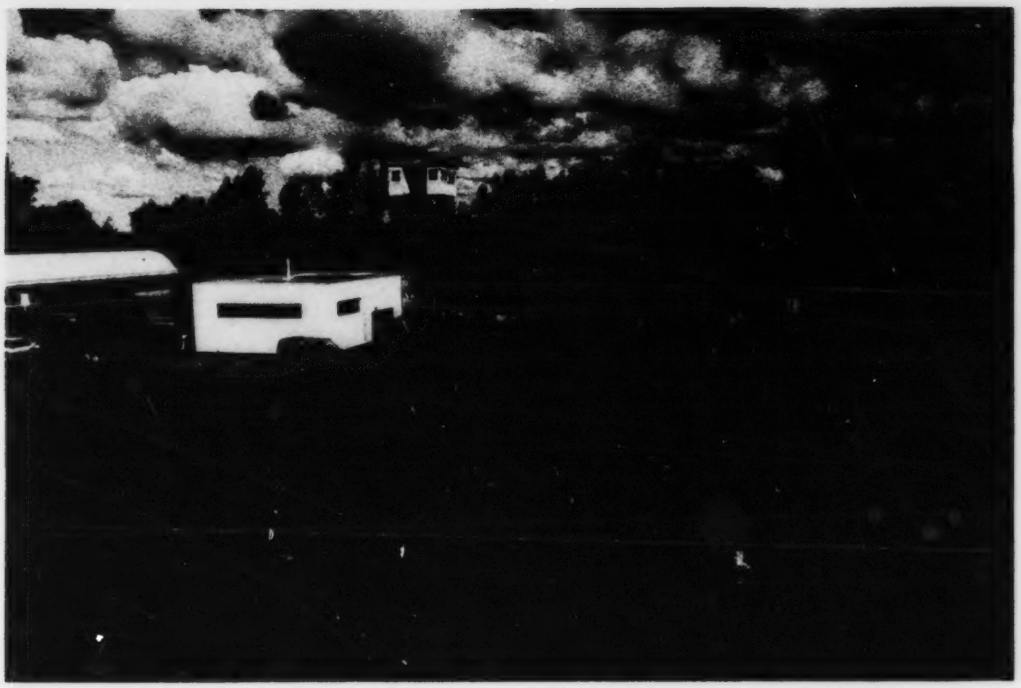
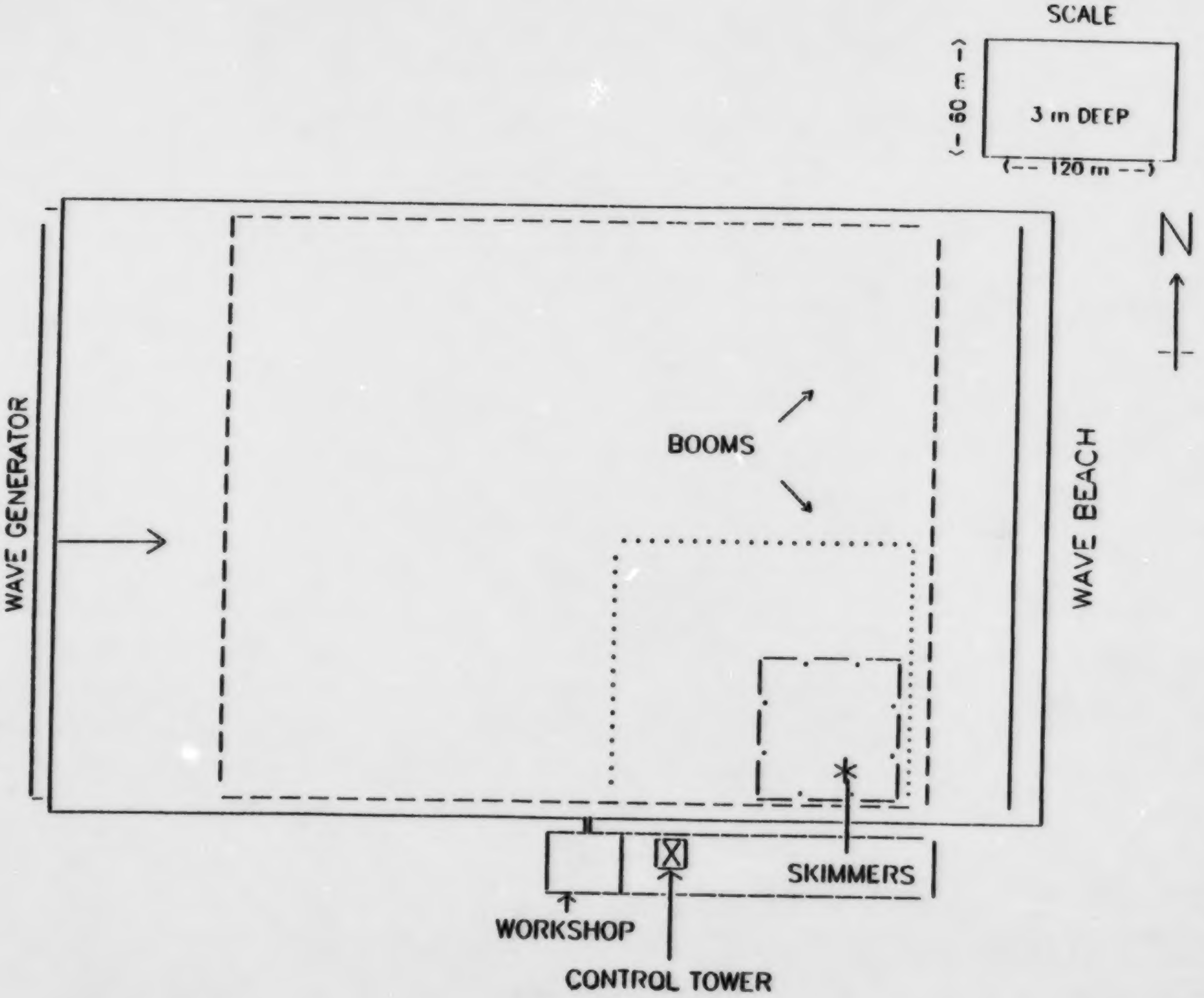


Figure 1: Test site – NRC Outdoor Ship Manoeuvring Basin and Building M–42

Figure 2: Wave tank (looking towards wave beach)

Figure 3 : Boom layout in wave tank


SCALE
<- 60 m ->
3 m DEEP
<-- 120 m -->
N
WAVE GENERATOR
BOOMS
WAVE BEACH
SKIMMERS
WORKSHOP
CONTROL TOWER

2.2 The Skimmers

Four skimmers were tested, the Walosep W–2 (Figure 4), the Framo–ACW 400 (Figure 5), the GT–185 (Figure 6), and the Heavy Oil Skimmer (Figure 7). Detailed specifications of each may be found in Appendix I. These four skimmers were selected for the test program for the following reasons. As noted previously, the Walosep, manufactured by Mattssonprodukter, of Sweden, was singled out in the ESRF countermeasures study (S.L. Ross and Hatfield 1986) for its potential applicability to waxy oils. The Framo skimmer (manufactured by Frank Mohn of Norway) was of interest because it is the primary skimmer in the countermeasures arsenals of both industry and Coast Guard on the East Coast. Similarly, the GT–185 (manufactured by Pharos Marine of Sweden) is an important part of the Coast Guard inventory. The prototype Heavy Oil Skimmer was developed by Canpolar and the Coast Guard specifically for viscous bunker oils. The three latter skimmers were involved in the recent field trials offshore St. John's.

The hydraulic arm of the Framo unit was used to deploy and position each of the skimmers within the test area. Both the ACW–400 and Heavy Oil Skimmer heads were powered by the Framo diesel/hydraulic power–pack mounted on the unit. The GT–185 and Walosep W–2 skimmer heads were powered by a GT–185 diesel/hydraulic power–pack. This power–pack (delivering up to 80 l/min @ 50–60 bar) did not produce sufficient hydraulic power for the Walosep W–2 pump (requiring 65 l/min at 170 bar) thus the pump could only be operated at up to 35% of its capacity. Fittings were not available to connect the Walosep W–2 to the Framo diesel/hydraulic power–pack (producing up to 250 l/min @ 250 bar).

Two MI–30 disc skimmers, although not tested, were used to recover oil that escaped the test area.

Figure 4: The Walosep W–2 skimmer

Figure 5:
The Framo ACW–400 skimmer head

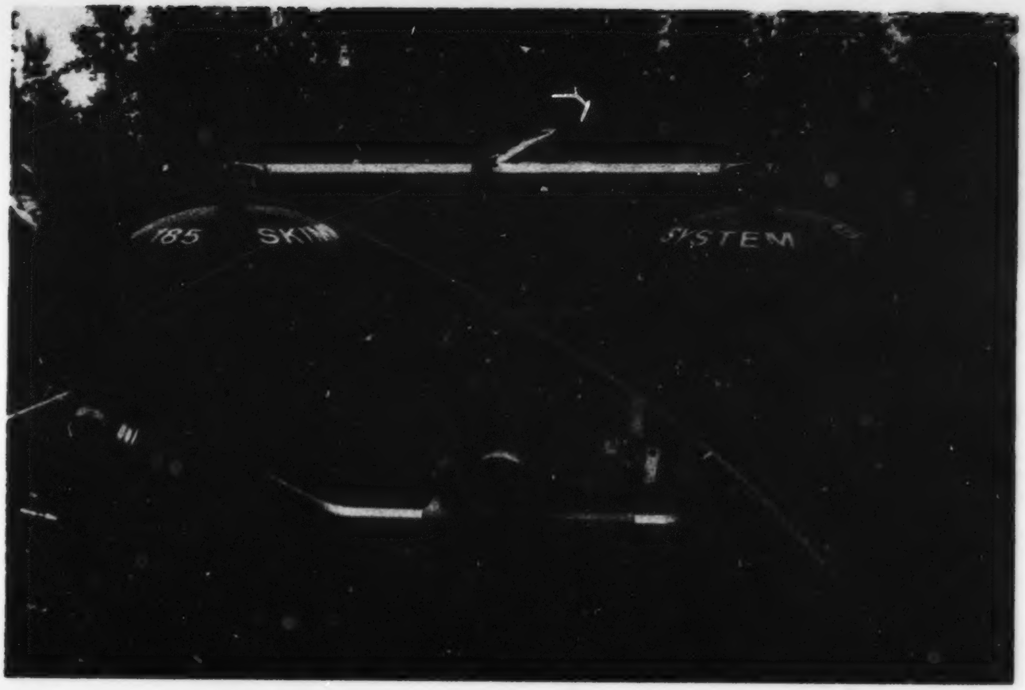

185 SKIM
SYSTEM

Figure 6: The GT–185 skimmer

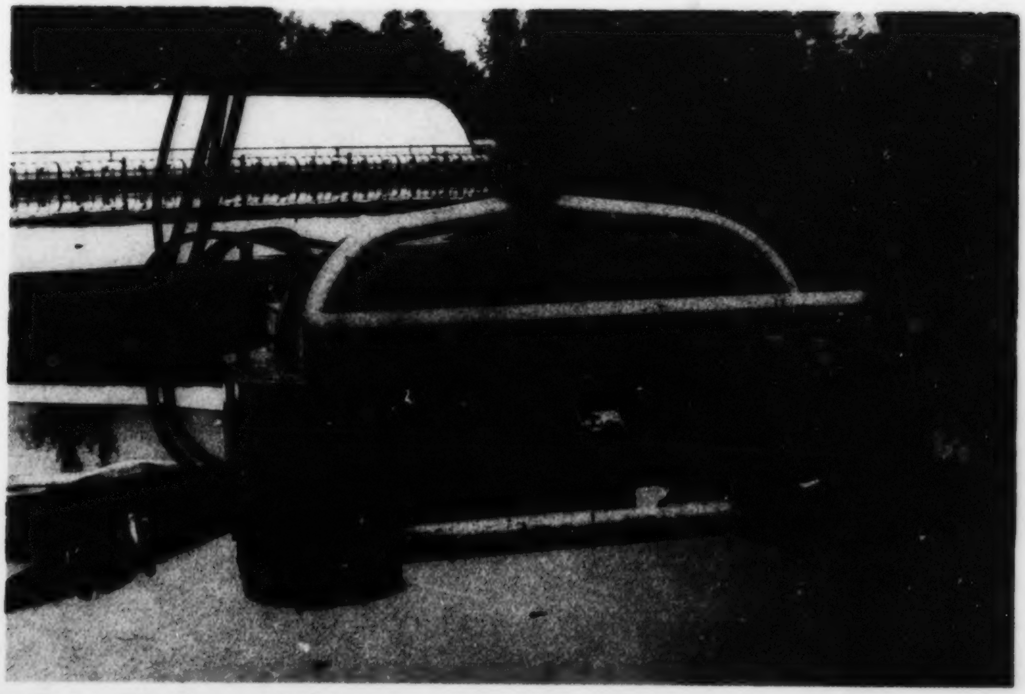


Figure 7: The Heavy Oil Skimmer

2.3 The Oils

Three oils were used to test each skimmer: IPL Sweet crude oil, a conventional pipeline crude from Alberta (similar in properties to the familiar Alberta Sweet Mixed Blend) served as a benchmark for the testing, a light Bunker C, representative of the viscous, residual fuel oils commonly spilled in Canadian waters; and Terra Nova C–09 crude oil, obtained from a Petro Canada well test on the Grand Banks during the summer of 1988. This oil is typical of the waxy crudes found at several locations on the Grand Banks. The first two oils were obtained from the Petro Canada refinery in Clarkson, Ontario. Table 1 gives the physical properties of each fresh oil.

TABLE 1

Properties of Test Oils (fresh)

Oil Type	Density @ 15°C (g/ml)	Viscosity @ 15°C cSt*	Pour Point (°C)
IPL Sweet crude	0.844	7.2	<0
Bunker C	0.958	9300	0
Terra Nova C–09 crude	0.834	36	10

* 1 centistoke = 1 mm^2/s

The Terra–Nova C–09 crude oil was heated to at least 45°C and circulated for several hours before each transfer on its journey from the rig to Ottawa. This procedure ensured that the waxes remained in solution in the oil and did not remain precipitated on cold tank walls after a transfer. Upon arrival and transfer in Ottawa the oil was kept heated in a steam–traced, insulated tanker.

The Bunker C was reused for each skimmer, weathering and reuse presumed to have little effect on its properties. Conversely, each test with crude oil was started with fresh crude.

2.4 Site Layout and Ancillary Equipment

Figure 8 shows a schematic diagram of the test site. The major pieces of ancillary equipment at the tank were: two 23 m^3 (5000 gallon), steam–traced portable tanks for dewatering and storage of used crude oil after testing; two 5 m^3 polyethylene, steam–traced tanks for dewatering and storage of Bunker C after each test; a 32 m^3 two–compartment, steam–traced, insulated tanker for storage of the fresh crude oil; a Cleaver–Brooks Model CBH–100 (980 kW) portable steam boiler to provide steam for tank heating and a steam siphon which was tested for its emulsion–breaking capabilities (Guenette 1989); a portable diesel/electric generator to power the steam boiler; two portable steam cleaners and several Spate 3–B portable pumps. The dewatering/storage tanks were placed in plastic–lined temporary berms to contain any accidental spillage.

Figure 9 shows the piping layout used for the tests; Figure 10 is a photograph of the layout taken from the control tower. Oil for each test was pumped from the tanker (or the 5 m^3 tanks in the case of Bunker C) into a manifold and then to a spill plate floating in the test area (Figure 11). This spill plate consisted of a plastic drum with an inflated truck tire attached to its rim for buoyancy and stability in waves. The discharge hose was suspended vertically into the drum with the end about halfway into the drum. This permitted the drum to move up and down with the waves without affecting the discharge hose. Once each test's oil had been pumped the hoses were flushed with water from the tank.

Recovered oil from a skimmer test was pumped through a test section of pipe where pressure, temperature and flowrate were measured and samples taken (see Section 2.5) then through a steam siphon (see Guenette 1989), into the manifold and then back to the spill plate. Upon completion of each test the skimmer pump was stopped and the hose from the manifold to the spill plate and the spill plate itself were flushed with water pumped from the tank. The skimmer pump was then restarted and the recovered oil pumped through the test section, steam siphon and manifold to the appropriate holding tank. Low and high pressure water was used to herd the last of the oil to the skimmer; final polishing of the test area and booms was accomplished by MI–30 skimmers and sorbents.

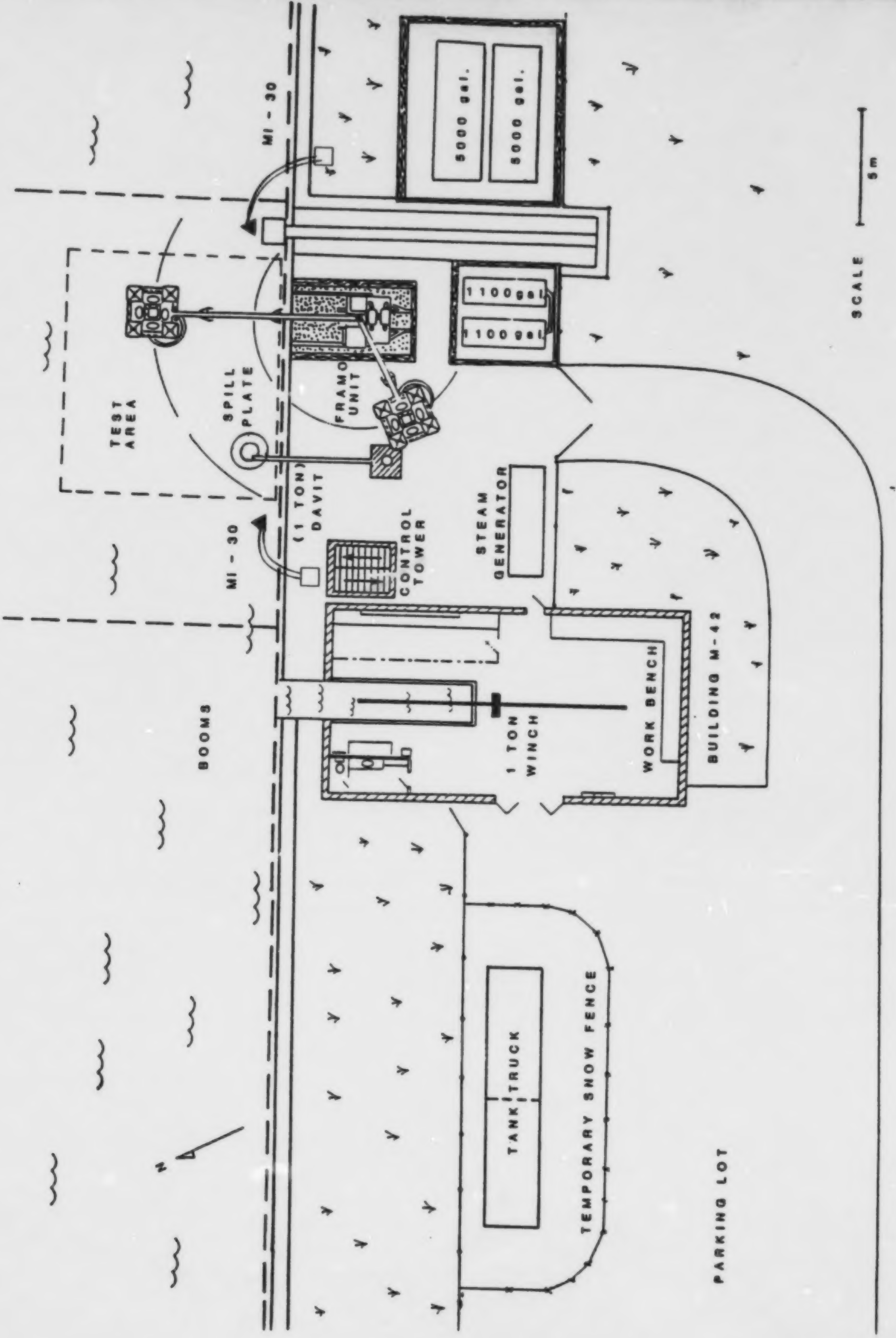

MI - 30
MI - 30
TEST AREA
SPILL PLATE
FRAMO UNIT
(1 TON) DAVIT
CONTROL TOWER
STEAM GENERATOR
5000 gal.
5000 gal.
1100 gal
1100 gal
BOOMS
1 TON WINCH
WORK BENCH
BUILDING M-42
TANK TRUCK
TEMPORARY SNOW FENCE
PARKING LOT
N
SCALE
5m

Figure 8: Equipment layout

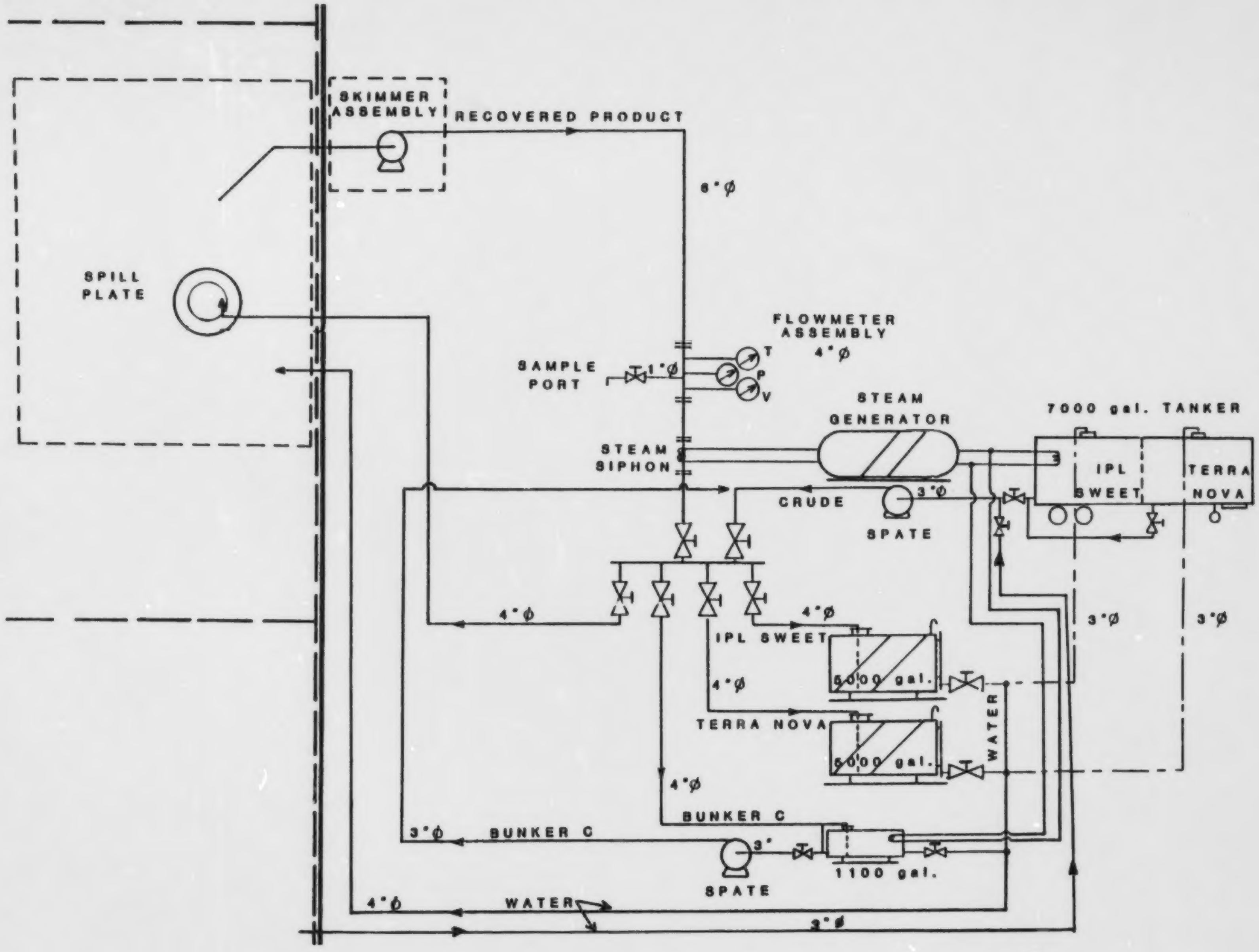

SPILL PLATE
SKIMMER ASSEMBLY
RECOVERED PRODUCT
6"Ø
FLOWMETER ASSEMBLY
4"Ø
T
P
V
SAMPLE PORT
1"Ø
STEAM GENERATOR
STEAM SIPHON
7000 gal. TANKER
IPL SWEET
TERRA NOVA
CRUDE
3"Ø
SPATE
4"Ø
4"Ø
IPL SWEET
5000 gal.
4"Ø
TERRA NOVA
5000 gal.
WATER
3"Ø
3"Ø
4"Ø
BUNKER C
3"Ø
BUNKER C
3"
1100 gal.
SPATE
4"Ø
WATER
3"Ø

Figure 9 : Piping layout

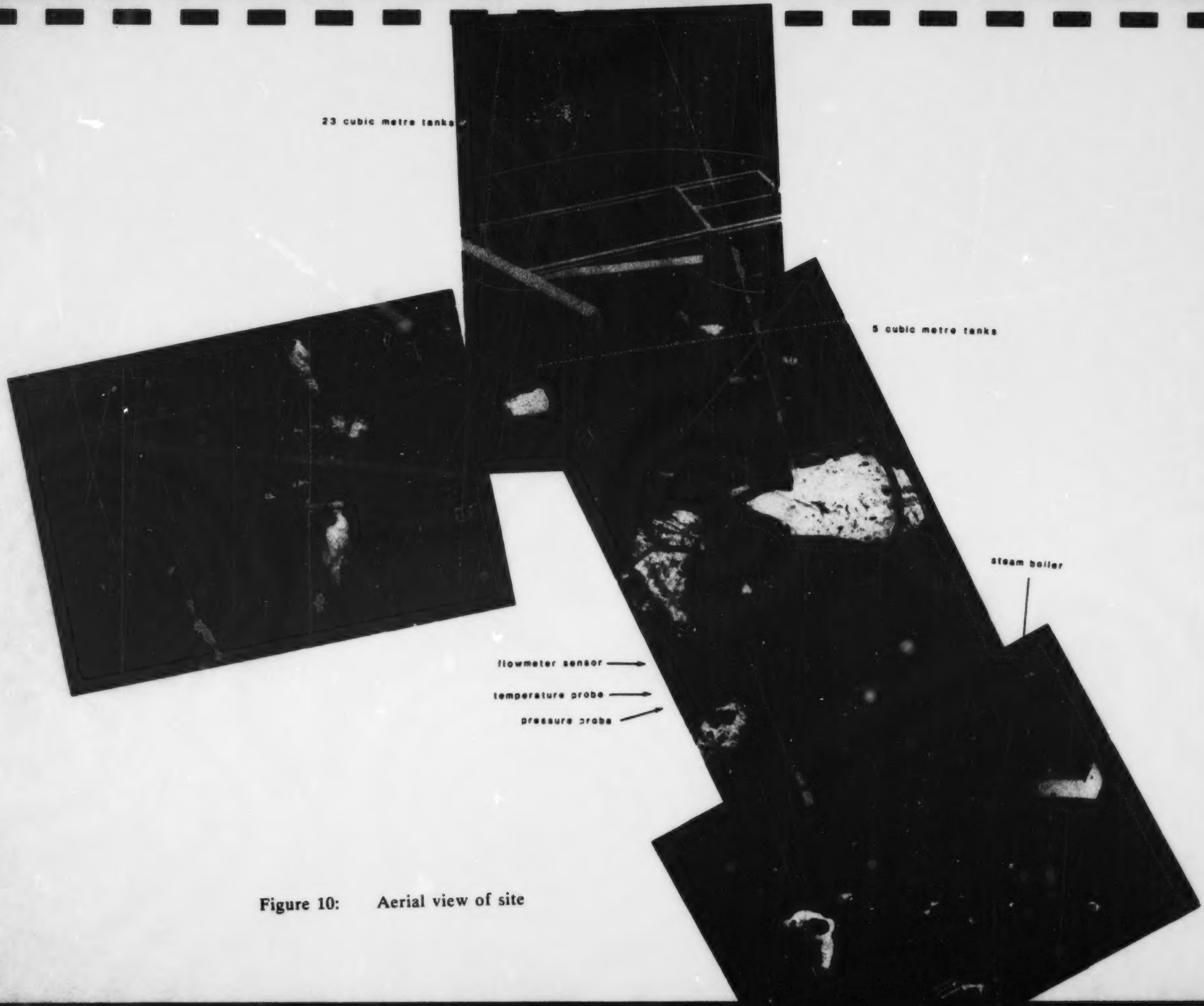

23 cubic metre tanks
5 cubic metre tanks
steam boiler
flowmeter sensor
temperature probe
pressure probe

Figure 10: Aerial view of site

spill plate

Figure 11: Spill plate in enclosed test area

2.5 Analytical Equipment and Techniques

2.5.1 Flow Measurement and Properties

The temperature, pressure and velocity of the recovered fluids were measured in a section of 10 cm diameter Schedule 40 steel pipe connected to the discharge hoses of the skimmers (Figure 12). The flow velocity was measured using a Dynasonics Model UFT-300 ultrasonic flowmeter with a Model T-500-HF transducer (see Appendix II). The transducer was mounted in the middle of the 2.4 m long pipe (10 pipe diameters from either end) and located on the side of the pipe about 45° down from the top. The signal from the flowmeter was fed to an IBM-XT compatible microcomputer inside Building M-42. The analog signal was converted to digital format by an IBM DACA converter board; the signal was recorded and plotted every 5 s in real time by an Unkelscope software package. This measurement system was calibrated by comparing an integration of its measurements of flow versus time against hand measurements of the fluid level in the holding tanks versus time at the end of selected tests. The tests for calibration were selected to cover the range of oil types and water contents representative of the skimmer test conditions. A linear correlation of the two sets of data resulted in a 4.5% difference between the two with a correlation coefficient of 0.964. The calibration curve may be found in Appendix II.

Also mounted on the test section of steel pipe were a hydraulic pressure gauge, bimetal dial thermometer and a 1" diameter sampling port for obtaining samples of recovered fluid for analysis.

Calculations of the pressure drop caused by the connection of the skimmer's 15 cm discharge hose to the 10 cm test section, 10 cm manifold and 7.6 m of 10 cm hose show that the system was equivalent to, at most, 3 x 7.5 m (25 foot) sections of 15 cm hose for fluid viscosities up to 1000 cSt and flows up to 50 m^3/hr.

2.5.2 Recovered Fluid Analysis

Samples of the recovered fluid were analysed immediately on-site to determine density, viscosity, free water content and emulsified water content.

Figure 12: Steel test section for flow measurement and sampling

Prior to obtaining a sample the sample port was opened and allowed to flow into a bucket to ensure that a representative sample was obtained. A sample was then collected by filling a 500 ml screw–top glass jar. Free water was determined by allowing the fluids to settle in the jar for 10 minutes, then measuring the height of the oil (or emulsion)/water interface with a calibrated tape measure. This technique has an estimated accuracy of ±5%.

An aliquot of oil (or emulsion) was then taken from the middle of the oil (or emulsion) layer, cooled to the recorded sample temperature in a water bath and then weighed on a Vernier balance in a calibrated density vial. The accuracy of this technique is about ±3%.

Viscosity was determined by timing the flow of an aliquot of the sample through the appropriate Ubeholde or Standard viscometer mounted in a water bath held at the recorded sample temperature. This technique has an estimated accuracy of ±5% for fluid homogeneous samples, however the viscosity measurements of waxy, Terra Nova C–09 crude at cooler temperatures are likely greatly in error due to the unique rheological behaviour of such oils at temperatures near their pour point (S.L. Ross and DMER 1988). As well, some samples of Bunker C contained such large drops of emulsified water that they behaved as a two phase system in the viscometers, thus rendering their flow time meaningless.

Emulsion water content was determined by measuring the oil content of a 1 gram aliquot of the sample diluted in toluene using a spectrophotometer. The accuracy of this technique is estimated at ±4%. The tests were conducted in fresh water which could have reduced slightly the emulsification tendency of the oils (Zagorski and Mackay 1982).

Full descriptions of the analytical procedures and calculations may be found in Appendix III.

2.6 Skimmer Testing Procedures

The following steps were undertaken for the test of each skimmer on each oil:

1. A known volume (determined by manually dipping the holding tank) of oil was placed in the test area. This volume was approximately 2.7 m^3 for the tests involving IPL Sweet crude, 3.4 m^3 for the tests involving Terra Nova C–09 crude and 4 m^3 for the Bunker C tests. These volumes equate to initial slick thicknesses of about 5, 6 and 7 cm respectively.

2. The oil was allowed to cool for about an hour to reach ambient temperature. In the case of three of the tests with the Terra Nova crude (the Heavy Oil Skimmer test being the exception) the oil was allowed to cool overnight and gel.

3. The skimmer was placed in the oil and recovery started. The recovered oil was recycled through the test section and manifold to the spill plate. Skimmer variables (i.e., pump rate, weir immersion, disc speed) were varied about every 20 minutes. About 5 minutes after each change (one every 30 minutes if no changes were made) a sample of the recovered fluid was taken for analysis. This procedure was followed for a period of about 2 hours, depending on the skimmer, with no waves in the tank.

4. The waves were then started and the above procedures repeated in waves. The wave height was measured at the tank wall beside the test area using a rule. Wave period was measured by obtaining the time for 10 crests to pass. Wavelength was determined by measuring the distance between successive crests.

5. Following completion of the tests in waves the skimmer was lifted out of the test area and Elastol was applied. This was accomplished by spraying an aqueous slurry of a preweighed amount of Elastol onto the oil in the test area. Mixing and reaction of the Elastol with the oil was accomplished either by continuing the waves during and after addition of the Elastol or by mixing using water pumped from the basin by a fire pump (Figures 13 and 14). For the one test of Elastol on Bunker C the Elastol was applied as a slurry in diesel oil to permit better penetration into the viscous Bunker C.

Figure 13: Application of slurried Elastol to oil by hose

Figure 14: Mixing of Elastol with oil using a fire pump

6. The skimmer was replaced in the tested oil and the test procedures above repeated over a short duration test (about 1 hr) involving measurements both with and without waves (if the results in waves were different than those obtained prior to Elastol addition).

7. Upon completion of the Elastol tests the discharge hose to the spill plate and the spill plate were flushed with water, and the recovered oil pumped to a holding tank. Once most of the oil had been skimmed from the test area hoses were used to herd the remaining oil to the skimmer. Once all possible oil had been removed the skimmer was raised out of the water and suspended over the test area. The skimmer was then cleaned with steam and hot water. The drippings from the skimmer were subsequently recovered by MI–30 skimmers and/or sorbents. The inner face of the test area booms were also flushed with water to eliminate contamination of the next batch of oil by Elastol–treated oil.

8. The cleaned skimmer was removed from the test site and the next day's skimmer delivered and rigged to the Framo unit ready for its test.

2.7 Calculation of Skimmer Performance Data

Three pieces of data were used to calculate performance for each skimmer setting: fluid recovery rate, free water content and emulsion water content. It was necessary to calculate the water entrainment rate of the skimming device because the recovered fluid was recycled back into the test area; this required analyzing the rate of increase of emulsified water in the recovered fluid over time. The equation used to accomplish this was:

$$Q_W = Q_F\ (FWC/100) + V_{oil}\ ((EWC_i - EWC_{i-1})/(AOC \times \Delta t))$$

where Q_W, Q_F = flowrates of entrained water and recovered fluid respectively (m^3/hr)

FWC = free water content of recovered fluid (%)

V_{oil} = volume of oil (water–free) in the test area (m^3)

EWC_i, EWC_{i-1} = water content of emulsion in recovered fluid in present and previous sample respectively (%)
Δt = time between samples (hr)
AOC = average oil content of emulsion over t (%)
= $(100 - (EWC_i + EWC_{i-1})/2)$

Corrected recovery rates are not reported as oil recovery rate but rather as oil/emulsion recovery rate (m^3/hr) because the skimmer was presented with an emulsion for some of its test, rather than pure oil. The corrected recovery rates were determined by:

$$O/ERR = Q_F - Q_W$$

The oil/emulsion content factor (%) was calculated from:

$$O/ECF = 100\,(1 - Q_W/Q_F)$$

Since the skimmers were operated in a static mode, calculation of oil recovered vs. oil presented was not possible.

3.0 RESULTS AND DISCUSSION

3.1 General

Table 2 shows the initial conditions (oil volume and thickness) for each of the tests. After the cleanup following the first test with Bunker C (with the Framo ACW–400) it was decided that the test schedule would be rearranged and all Bunker C tests performed on consecutive days. The reasons for this were: first, considerable oil was wasted during the cleanup and second, the cleanup required considerable effort. As such, the water content of the Bunker C used for the other skimmers increased steadily.

Due to unusually warm weather in the Ottawa area preceding and during the tests the water temperatures in the tank were not as low as desired. The major effect of this was that the Terra Nova C–09 crude, when fresh, was not at a temperature below its pour point. In order to attempt to overcome this problem the Terra Nova C–09 crude was placed in the test area the night before the tests of the Walosep W–2, GT–185 and Framo–ACW–400 skimmers. This allowed the oil to weather somewhat and cool to the lower night air temperatures. In the morning, the oil on the surface of the slick would have gelled (Figure 15). After about 30 minutes of testing, however, the bottom portion of the slick (in contact with the warmer water) would have mixed through the test area and the waxy oil would refluidize. Sunlight on the test slick seemed to accelerate the process. It was decided not to delay the Terra Nova C–09 crude tests until the water cooled further because of the considerable expense involved in waiting and the number of personnel and equipment at the site from St. John's.

TABLE 2

Initial Test Conditions

Skimmer Type

OIL TYPE	ACW–400	GT–185	WALOSEP W–2	H.O.S
IPL Sweet	2.7 47 17	2.7 47 18	2.6 45 15	2.6 45 18
Bunker C	4.0 69 18	2.5 (5.0) 43 (87) 18	2.5 (6.0) 43 (115) 14	2.5 (7.8) 43 (137) 17
Terra Nova C–09	3.4 59 13	3.3 57 12	3.3 57 15	3.5 61 15

Legend

INITIAL OIL VOLUME (m^3) (INITIAL EMULSION VOLUME (m^3))

INITIAL SLICK THICKNESS (mm) (INITIAL EMULSION THICKNESS (mm))

WATER TEMPERATURE (°C)

Figure 15: Terra Nova C–09 test slick gelled after overnight exposure

Figure 16 shows the variation in wave height measured at the test area as a function of time. Once the wavemaker was started at the selected setting the waves quickly built up to about 0.3 – 0.4 m in height. At the selected wavemaker setting the wave beach could not completely absorb the generated wave and a portion of the wave was reflected. As the generated and reflected waves drifted in and out of phase, the measured wave height increased to 0.7 – 0.8 m then decreased to about 0.4 – 0.5 m. The period of this phase drift was about 1.5 – 2 hours. This phenomenon proved useful as wave height became an unintentional, additional parameter in each test, providing further information on the abilities of each skimmer.

3.2 Skimmer Tests

The following is a summary description of each test performed with the four skimmers; raw data and field notes may be found in Appendix IV.

3.2.1 Framo ACW–400

3.2.1.1 Test With IPL Sweet Crude

Figure 17 shows the fluid recovery rate of the Framo ACW–400 skimmer with IPL Sweet crude. Also shown are the results of the analyses for free and emulsified water, viscosity and density of the recovered fluid plotted on a common time axis for comparison with the recovery rate.

From 11:35 to 12:15 the disc speed was set at 10 rpm with the hydraulic pressure to the pump set at 50 bar and the weir up. From 11:57 to 12:15 the skimmer (Figure 18) was judged to be operating at steady state recovering some 33 m^3/hr (composed of 32 m^3/hr of emulsion and 1 m^3/hr water). The emulsion water content in the recovered fluid was about 35% at this point (although this may be an analysis error– a more likely value would be 5 – 10%) and the viscosity of the fluid was about 15 cSt. At 12:15 the disc speed was increased to 15.6 rpm and maintained at this setting until 12:35. The steady state fluid recovery rate was measured at 47 m^3/hr (46 m^3/hr

FIGURE 16

VARIATION IN WAVE HEIGHT WITH TIME

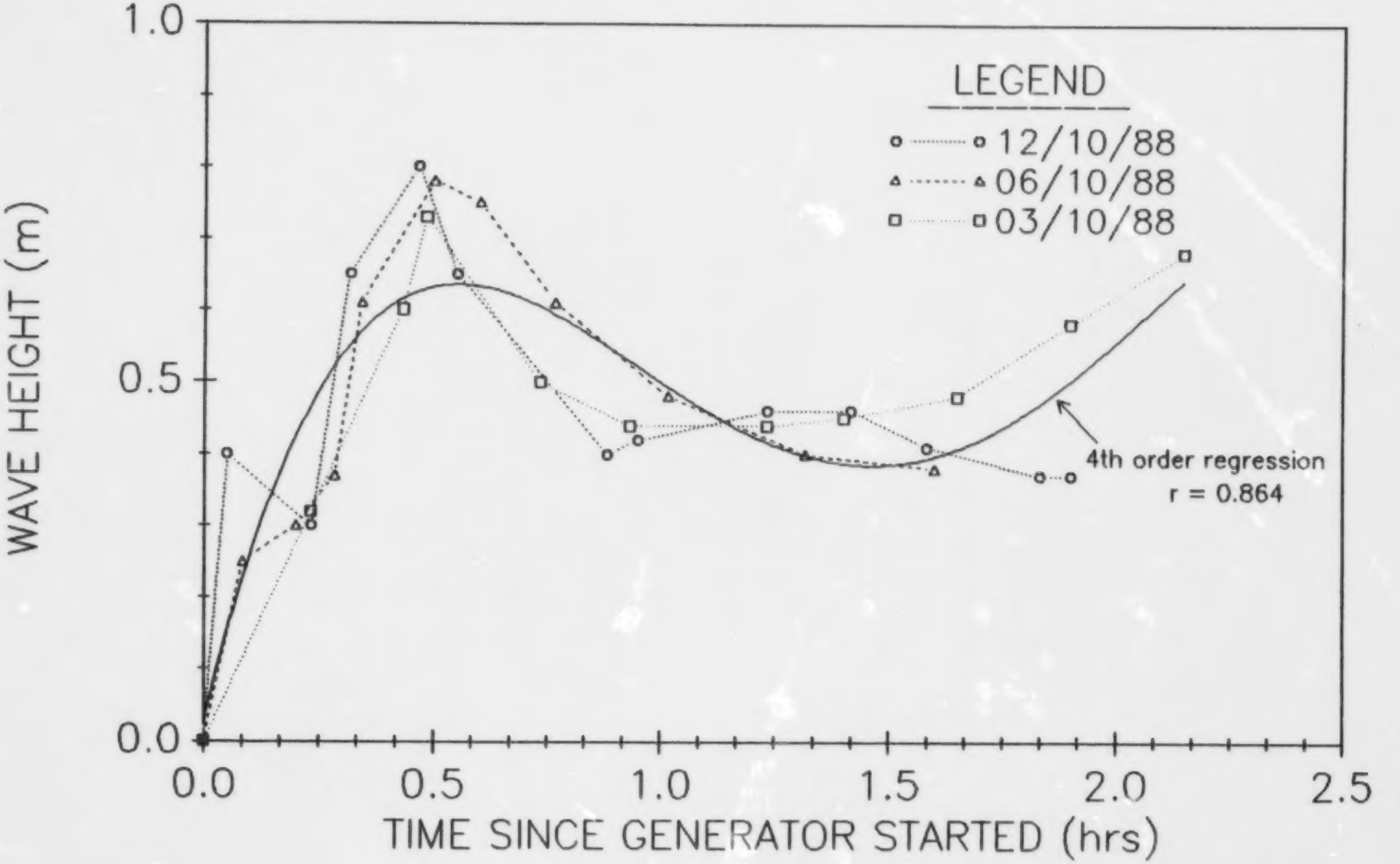


FIGURE 17

ACW-400 with IPL Sweet

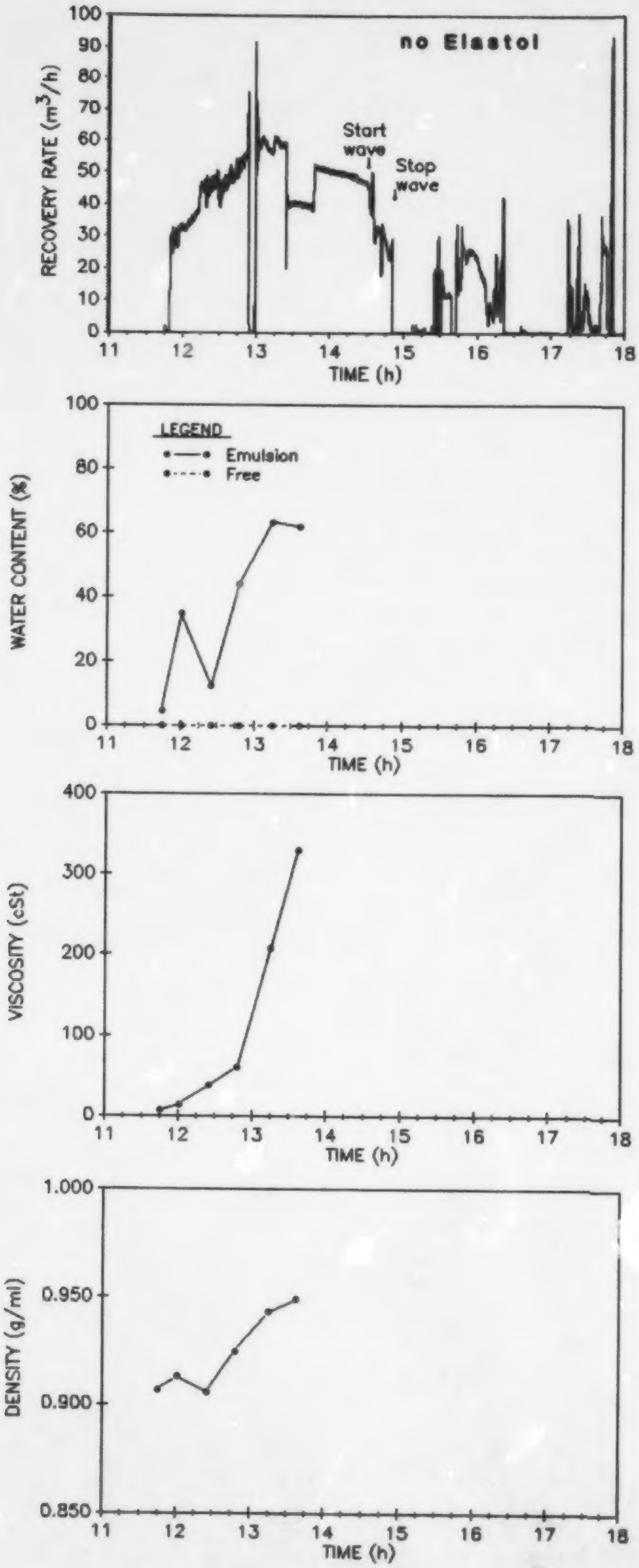


Figure 18: Framo ACW–400 operating in IPL Sweet crude oil

emulsion and 1 m^3/hr water) with an emulsion water content of 12% and a viscosity of 37 cSt. At 12:35 the disc speed was further increased to 17.1 rpm which resulted in a slight increase in fluid recovery rate to 54 m^3/hr (48 m^3/hr emulsion and 6 m^3/hr water) and increases in emulsion water content to 44% and viscosity to 60 cSt. From 12:50 to 13:00 the skimmer was stopped and lifted out of the water to lower the weir.

From 13:00 to 13:25 the skimmer was operated with a disc speed of 17.1 rpm, pump hydraulic pressure at 59 bar and the weir set 5 cm down from the oil surface. The measured recovery rate at these conditions was 58 m^3/hr (53 m^3/hr emulsion and 5 m^3/hr water). The recovered fluid had an emulsion water content of 63% and viscosity of 207 cSt. It was worthy of note that no significant free water was measured in any of the samples taken; this is likely due to the action of this skimmer's internal centrifugal pump rapidly and completely emulsifying any water entering the sump. At 13:25 the weir was raised.

From 13:25 to 13:45 the disc speed was reduced to 10 rpm and operated at similar settings to those used initially. Fluid recovery rate was measured at about 40 m^3/hr (with no free water) with an emulsified water content of 62% and a viscosity of 330 cSt. This represents a 20% increase in recovery rate over that measured previously with an increase in viscosity from 15 to 330 cSt. The skimmers discs appear to recover more viscous oils (in this viscosity range) more effectively. At 13:45 the disc speed was increased to 15.7 rpm with a corresponding increase in recovery rate to 53 m^3/hr, representing a 13% increase over the recovery rate at the earlier, identical setting. No samples were taken during this segment of the test, but the oil was visually more emulsified and viscous than previously. The skimmer settings were maintained from 13:45 to 14:35; over this period the recovery rate slowly declined to a low of 47 m^3/hr at 14:30. Since no physical property data is available for this time period, the reasons for this decline are not clear.

At 14:35 the wavemaker was started and by 14:45 the wave height was 0.5 m with a period of 4 s and a wavelength of 17 m. With the skimmer settings unchanged from before, the recovery rate dropped considerably to 33 m^3/hr and thence, over the next 15 minutes, to 25 m^3/hr. The reason for this is illustrated in Figure 19; under the influence of wave action, the skimmer head, hard-mounted to the hydraulic arm of the Framo unit, began to rock and pitch, pushing oil away from the banks of skimmer discs facing the waves. As well the action of the skimmer head dispersed oil into the water column and also created an oscillating current which pumped oil beneath the containment boom surrounding the test area.

This latter effect caused the test to be stopped, since much of the oil was escaping from the test area. No test of Elastol was conducted with the Framo ACW-400 skimmer, but Elastol was added to the oil that had escaped the test area to aid its recovery with MI-30 skimmers. The remainder of the recovery rate data was obtained during cleanup of the test area while pumping to the holding tank.

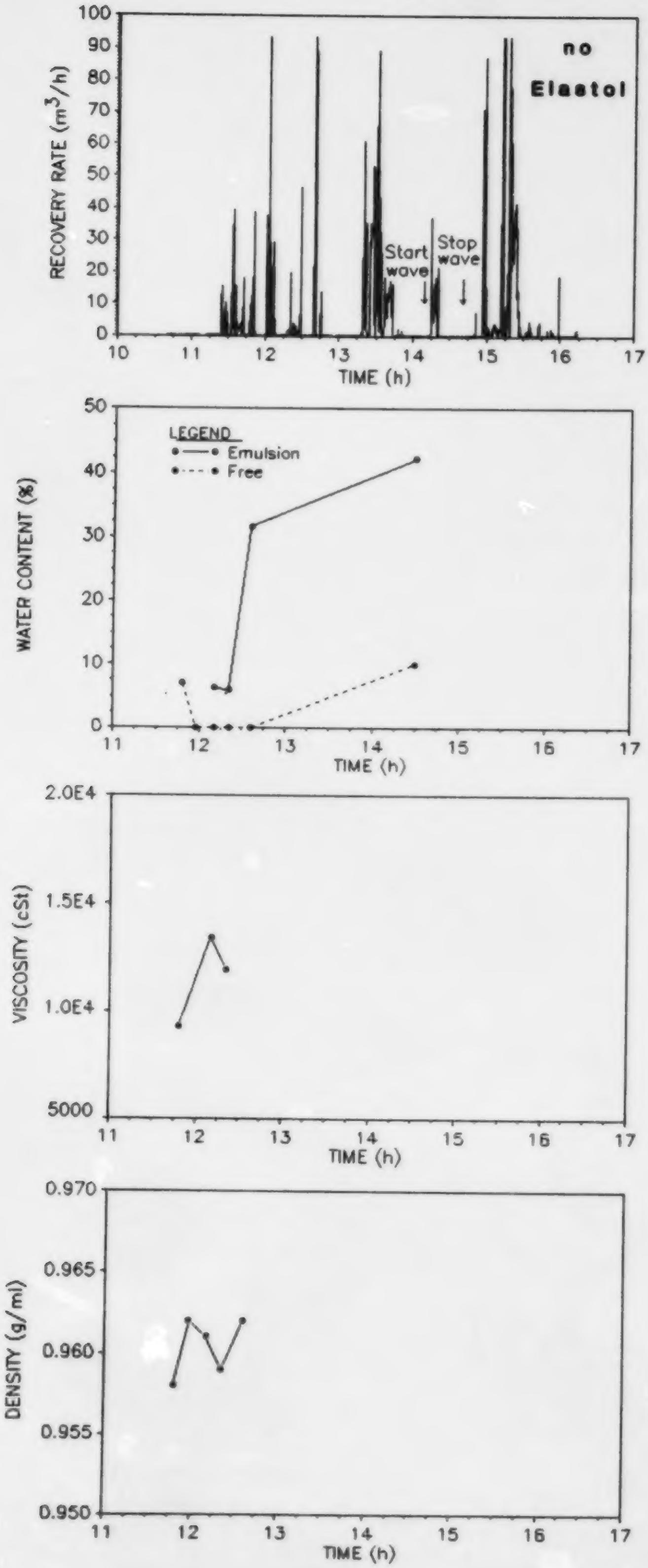
3.2.1.2 Test with Bunker C

Figure 20 shows the results for the test of the Framo ACW-400 with Bunker C. The skimmer disc speed was set at 10 rpm and the pump hydraulic pressure at 140 bar with the weir up from 11:39 to 13:00 and from 13:45 to 14:05. During this period the recovery rate for the skimmer was very erratic and slow, averaging about 5 m^3/hr early in the tests and up to 10 m^3/hr near the end, with pulses of water pumped at rates of up to 95 m^3/hr. The emulsified water contents of the samples taken increased to 45% by the end of the tests, equivalent to a water recovery rate of 1.2 m^3/hr, free water contents ranged from 0 – 10%. It was difficult to distinguish the difference between free and emulsified water because the high viscosities of the oil permitted large water drops to remain in suspension for the specified sample settling time. Similarly, only the first few samples were suitable for viscosity analysis because the presence of large water drops rendered the measured flow times meaningless. The viscosity of the initial samples of the Bunker C ranged from 9300 to 13,500 cSt.

Figure 19: Framo ACW–400 skimmer pushing oil away from discs in waves

FIGURE 20

ACW-400 with BUNKER C



At 14:10 the wave maker was started and by 14:20 the waves were measured at 0.5 m high with a period of 4 s and a wavelength of 18 m. In waves, the pickup of Bunker C by the discs seemed to improve; however, the high viscosity of the oil (with an emulsified water content of 40%) slowed the discs from 10 to about 2 rpm. The recovery rate over the short test in waves averaged about 13 m^3/hr, including about 10% free water. The wavemaker was shut off at 14:30 because of the previously noted problem with the skimmer head pumping oil under the containment boom.

From 15:00 to 15:15 the Framo ACW–400 skimmer was used to recover the Bunker C from the test area and pump it to the holding tank at a rate of about 4 m^3/hr with the discs off and the weir down. At 15:15 the steam siphon was used to assist the pumping. The siphon was fed steam at a rate of about 130 kg/hr raising the temperature of the Bunker C passing through the siphon from about 20°C to between 40 and 70°C. The action of the steam siphon also greatly reduced the head against which the Framo ACW–400 skimmer had to pump. The skimmer for this portion of the test was still operated with the discs stopped and the weir full down; recovery, though erratic increased to the 30 m^3/hr range with little change in emulsified water content and no free water. No Elastol test was planned for this trial.

The Framo ACW–400 could not effectively recover the Bunker C, although the use of an in–line steam siphon to reduce the head against which the skimmer had to pump, dramatically increased the device's recovery rate.

3.2.1.3 Test with Terra Nova C–09

Figure 21 shows the results obtained with the Framo ACW–400 skimmer and Terra Nova C–09 crude oil. The tests were performed with a water temperature of 13°C; the oil had been placed in the test area the previous evening and cooled overnight. The air temperature above the slick at the start of the test was 5°C. As a result, the surface of the Terra Nova C–09 crude had gelled and solidified (Figure 22).

FIGURE 21

ACW-400 with Terra Nova Crude

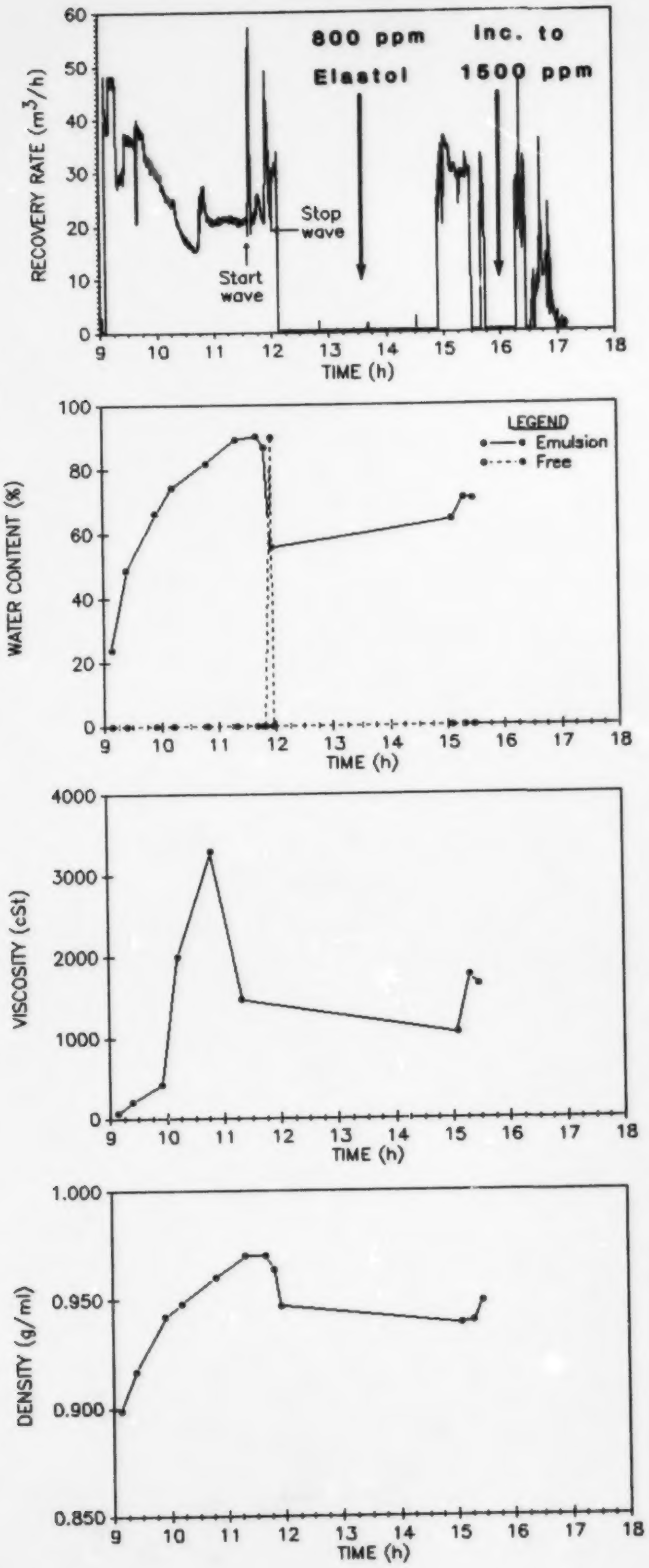


Figure 22: Appearance of Terra Nova C–09 test slick prior to commencing Framo ACW–400 test

The disc speed and pump hydraulic pressure were set at 10.4 rpm and 40 bar respectively from the start of the test at 09:06 until 09:30. From 09:06 to 09:19 the weir had been inadvertently lowered and water drawn in. At 09:19 the weir was fully raised. At this point the skimmer was recovering a 48% water–in–oil emulsion with a viscosity of 205 cSt. It should be noted that this viscosity is not representative of that of the oil slick since the sample analysed had passed through the skimmer's centrifugal pump. This shearing action would have dramatically changed the rheological properties of the waxy Terra Nova C–09 crude and lowered its viscosity. In addition, due to the solidified nature of the oil, the recovered oil recycled to the test area tended to channel its way back to the skimmer (Figure 23). Attempts were made to reduce this by moving the skimmer head as far as possible from the spill plate, but the effect was never eliminated completely.

From 09:19 to 09:30 the recovery rate was 29 m^3/hr of a 50% water–in–oil emulsion with a viscosity of 205 cSt. At 09:30 the disc speed was increased to 14.3 rpm with a resultant increase in recovery rate to 36 m^3/hr (33.5 m^3/hr emulsion and 2.5 m^3/hr water). At 09:50 the disc speed was further increased to 16.8 rpm. This had the effect of increasing the emulsification from 66% water in the oil after 5 minutes to 75% after 22 minutes (equivalent to a flowrate of 3.25 m^3/hr water) and increasing the emulsion viscosity from 420 cSt after 5 minutes to 2015 cSt after 22 minutes. At 09:50 the recovery rate was 38 m^3/hr (35 m^3/hr emulsion and 3 m^3/hr water) a slight increase over the rate at a disc speed of 14.3 rpm, however the recovery rate decreased steadily to 16 m^3/min (14 m^3/min emulsion and 2 m^3/min water) at 10:45 despite increases in pump hydraulic pressure to 50 then 60 bar and lowering the weir 5 cm at 10:20. During this time the recovered emulsion water content and viscosity increased steadily to 82% and 3300 cSt respectively. Between 10:45 and 10:53 the weir was fully lowered and the pump hydraulic pressure increased to 65 bar. This had the effect of stabilizing the recovery rate at 22 m^3/hr; (with about 0.5 m^3/hr of water being entrained over the next 42 minutes) the water content of the recovered emulsion was 90% and it had a viscosity of 1500 cSt.

Figure 23: Channeling of recycled Terra Nova C–09 crude oil from spill plate to skimmer

It is apparent that even during these calm water trials significant quantities of water were being entrained by the skimmer and mixing with the waxy oil in the centrifugal pump to form a viscous emulsion. This is likely a direct result of the yield stress developed in a waxy oil at temperatures below its pour point (S.L. Ross & DMER 1988) which greatly restricts its flow, allowing water to contact the collection surfaces of the skimmer.

At 11:36 the wavemaker was started; the wave height increased from 0.3 m at 11:38 and 11:45 to 0.35 m at 11:50, 0.48 m at 11:55 and 0.75 m at 12:00 (see also Figure 16). At this point the action of the skimmer head began pumping oil beneath the test area containment booms and the wavemaker was shut off.

From 11:36 to 11:50 the disc speed was set at 16.8 rpm, the pump hydraulic pressure was set at 65 bar and the weir was fully raised. Under these conditions the Framo ACW recovered a 90% water–in–oil emulsion at a rate of about 23 m^3/hr with no free water. At 11:50 the disc speed was reduced to 14.3 rpm which resulted in no significant change in recovery rate. After 11:55 the wave heights increased above 0.5 m and the skimmer recovery rate increased to 35 m^3/hr but the recovered fluid was 90% free water (equivalent to an emulsion recovery rate of 3.5 m^3/hr). The water content of the emulsion was 56%. This reduction in viscosity and water content reflects the fact that the wave action mixed the gelled oil not in the vicinity of the skimmer and spill plate with the emulsified oil near the skimmer and spill plate. The swaying and rocking action of the skimmer head at wave heights above 0.5 m pushed the oil away from the skimmer and occasionally forced one side of the skimmer weir below the water level. At 12:07 this portion of the test was stopped and the skimmer raised out of the oil.

The results of this portion of the test compare well with the performance of the Framo ACW–400 measured offshore with another waxy oil (S.L. Ross 1987). In those tests the device recovered 22 m^3/hr of emulsion with a viscosity of 1900 cSt and 17 m^3/hr of water in waves 0.75 – 1 m high.

At about 13:30 an aqueous slurry of Elastol was sprayed on the emulsion in the test area. The calculated concentration of Elastol in the oil (as opposed to the emulsion) was 800 ppm. The Elastol was mixed into the emulsion using a fire hose and allowed to react for 1.5 hr. At this point the emulsion was tacky, but did not form the strands characteristic of Elastol–treated oil.

At 14:55 the Framo ACW–400 skimmer was lowered into the emulsion and started with a disc speed of 10 rpm a pump hydraulic pressure of 50 – 55 bar and the weir up. Between 14:55 and 15:55 the recovery rate averaged about 30 m^3/hr (27 m^3/hr emulsion and 3 m^3/hr water) of a 64% water–in–oil emulsion with a viscosity of 1060 cSt. No free water was measured. At 15:15 the disc speed was increased to 14.3 rpm and the pump pressure increased to 60 bar. These changes had little effect on the measured recovery rate. The recovered fluid consisted of a 71% water–in–oil emulsion with a viscosity of 1765 cSt. At 15:22 the disc speed was further increased to 15 rpm and at 15:25 the weir was lowered to 5 cm below the emulsion level. Neither of these changes had any significant effect on measured recovery rate or recovered fluid properties. At 15:30 this portion of the test was stopped and additional Elastol (increasing the total concentration to 1500 ppm in the oil) was sprayed on and allowed to react for about ½ hour. At this point the emulsion was exhibiting Elastol–treated oil behaviour. The skimmer was replaced in the emulsion and the recovered fluid pumped to a holding tank. Initial recovery rate measurements indicated that the increase in Elastol concentration did not enhance the skimmers performance over the lower concentration results.

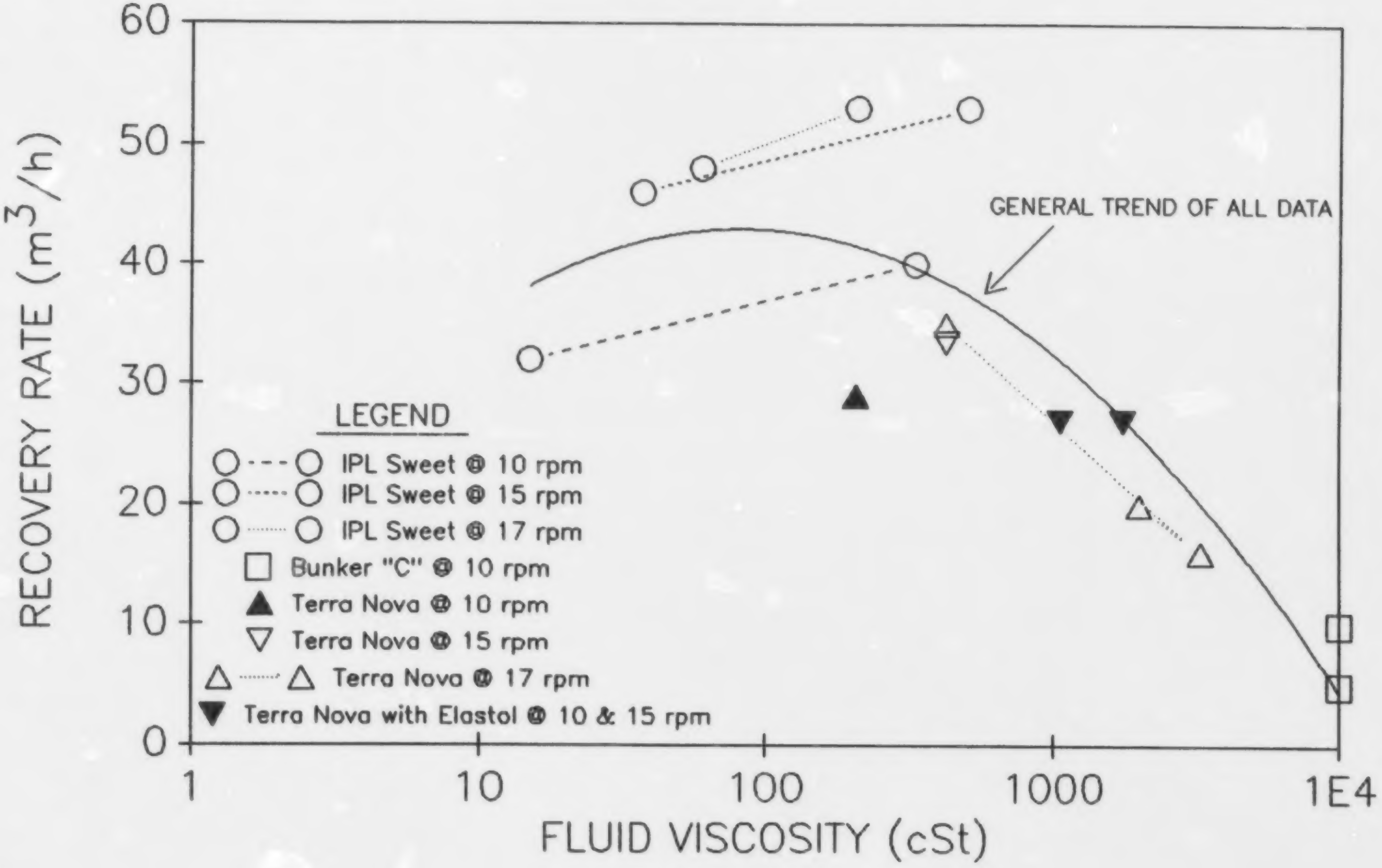
A comparison of recovery rate records pre and post–Elastol addition for similar operating conditions and recovered fluid properties (i.e., 09:19 to 09:30 vs. 14:55 to 15:55 and 09:30 to 09:50 vs. 15:55 and 15:25) indicates that Elastol treatment of the slick had little effect on fluid recovery rates (29 m^3/hr vs. 30 m^3/hr at 10 rpm and 36 m^3/hr vs. 32 m^3/hr at 14 rpm) or water recovery (2.5 m^3/hr vs. 3 m^3/hr).

3.2.1.4 Comparison

Figure 24 shows the steady–state oil/emulsion recovery rates (O/ERR) measured for the Framo ACW–400 skimmer as a function of recovered fluid viscosities. The recovery rates have been corrected for water entrainment. The general trend of all the data points was an increase in recovery rate with increasing viscosity for oils or emulsions with viscosities up to several hundred centistokes; recovery rates decreased

FIGURE 24

RECOVERY RATE vs VISCOSITY
FRAMO ACW-400



dramatically as the viscosity of the fluid increased above 1000 centistokes. For oils with viscosities less than several hundred centistokes, increasing disc speed increased recovery rate (by about 10 m^3/hr for 10 to 15 rpm and an additional 2–3 m^3/hr for 15 to 17 rpm). Comparison of the data for the IPL Sweet tests with that for the Terra Nova tests shows that, for equivalent viscosities, the Terra Nova was recovered at a rate 30–40% lower than the IPL Sweet at both 10 and 14 rpm disc speed. Water entrainment was also about 3 times greater for the Terra Nova tests (3 m^3/hr) than for the IPL Sweet tests (1 m^3/hr).

Oil/emulsion content factors in calm conditions for the Framo ACW–400 ranged from 80% to 97% with IPL Sweet at a disc speed of 17 and 10 rpm; from 75% to 88% with Bunker C and from 88% to 93% with Terra Nova at disc speeds of 17 and 10 rpm. In waves, the oil content factor decreased considerably.

In general the Framo ACW–400 skimmer and unit performed reliably throughout the trials and recovered lower viscosity oil and emulsion effectively in calm conditions; however, its propensity to strongly emulsify oil and water entering the pump and the fact that it tended to push oil away from itself in waves exceeding 0.5 m with a 4 s period, detracted from its overall performance. This latter problem could perhaps be overcome by modifying the skimmer head and associated hoses to permit the device to float freely, independent of the hydraulic arm.

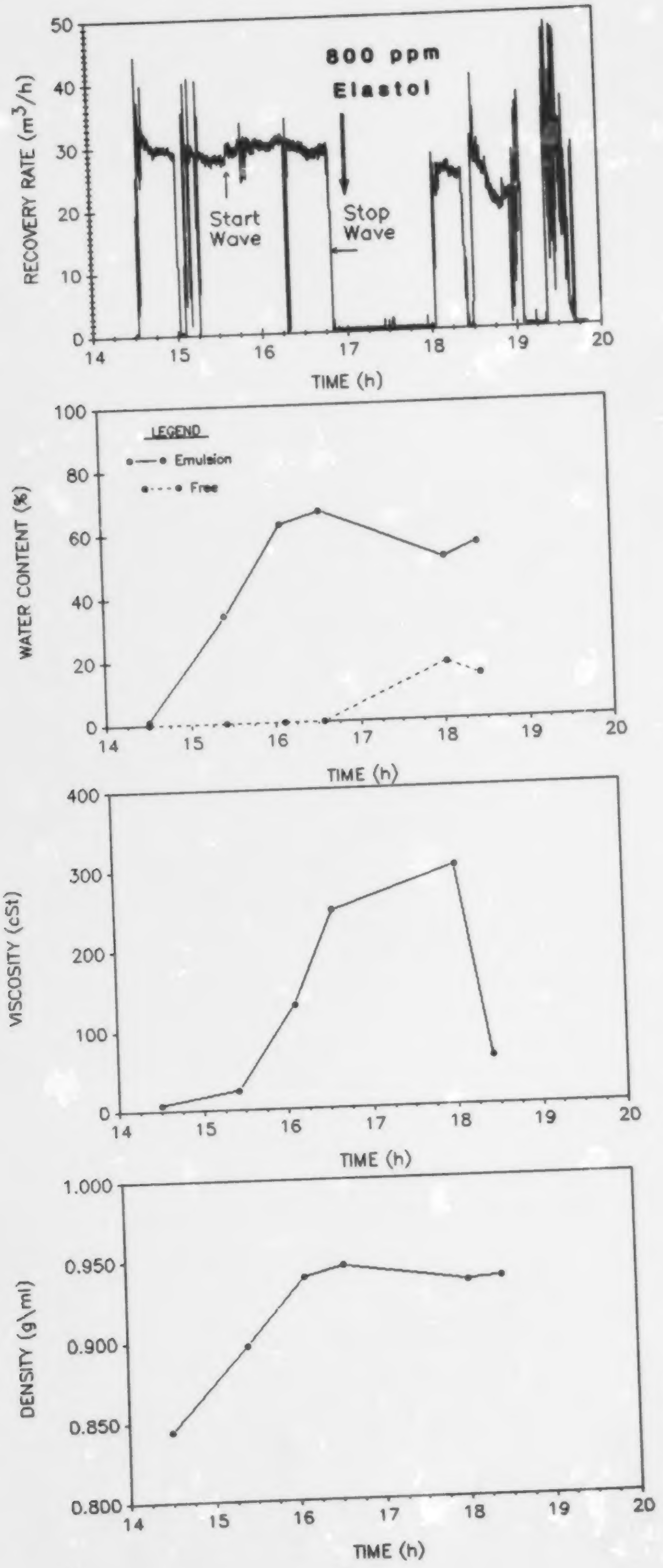
3.2.2 GT–185

3.2.2.1 Test with IPL Sweet Crude

Figure 25 shows the recovery rate of the GT–185 skimmer, with Light Oil Adapter installed (Figure 26), while operating in the IPL Sweet crude at a temperature of 18°C. The skimmer was operated throughout the test with the power–pack hydraulic valve full open (50–55 bar) and the engine running at 2500 rpm. From 14:30 to 14:42 the weir was being adjusted to 2 cm below the oil surface.

FIGURE 25

GT-185 with IPL



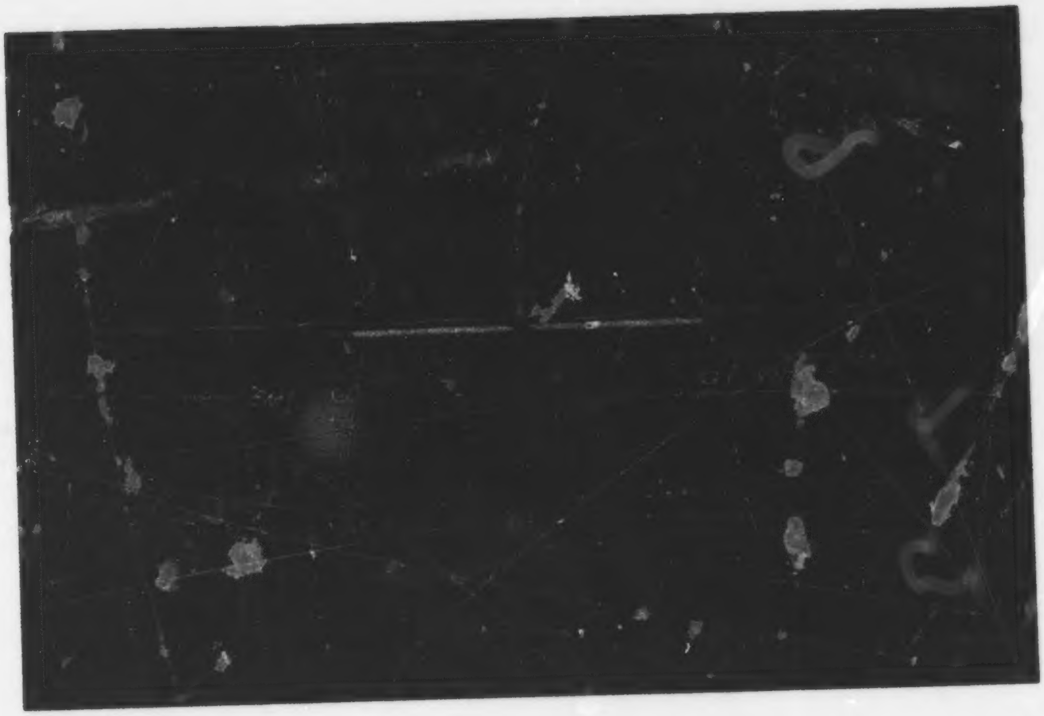


Figure 26: GT−185 skimmer with Light Oil Adapter in place

From 14:42 to 15:00 the GT–185 was operating at steady state recovering 30 m^3/hr of low viscosity (about 10 cSt) fluid with very little emulsification. From 15:00 to 15:20 the weir was further adjusted down to 4 cm below the oil surface (the initial thickness of the oil layer was 4.7 cm). From 15:20 to 15:37 the GT–185 recovered fluid at a rate of 29 m^3/hr, consisting of 26 m^3/hr of a 20 – 30% water–in–oil emulsion with a viscosity of 24 cSt and 3 m^3/hr water.

At 15:37 the wave maker was turned on and at 15:45 the weir was raised to 1 cm below the oil surface. From 15:45 to 16:20 the skimmer operated in 0.57 m high waves with a period of 4 s. The device followed the waves very well. Over this time period the GT–185 recovered fluid at a rate of 30 m^3/hr (28 m^3/hr emulsion and 2 m^3/hr water) with an emulsified water content of 62% and a viscosity of 130 cSt.

From 16:20 to 16:23 the weir was raised further to just below the oil surface. From 16:23 to 16:50 the GT–185, operating in waves from 0.4 to 0.75 m high recovered a 65% water–in–oil emulsion with a viscosity of 250 cSt at a rate of about 29 m^3/hr with almost no water being drawn into the skimmer at this setting. At 16:50 the wavemaker and skimmer were stopped to permit Elastol treatment of the slick.

At about 17:00 an aqueous slurry of Elastol was sprayed onto the emulsion in the test area to give a concentration of Elastol in oil of 800 ppm. The Elastol was mixed with the emulsion using a fire hose for 15 minutes.

At 18:00 the skimmer was replaced in the emulsion and restarted, with the weir set just below the oil surface. From 18:00 to 18:10 the GT–185 recovered fluid at a rate of 23 m^3/hr including 18% free water (4 m^3/hr) and a 50% water–in–oil emulsion with a viscosity of 300 cSt (19 m^3/min). At 18:10 the weir was adjusted down to 1 cm below the oil surface and operated at this setting to 18:30. From 18:10 to 18:15 the recovery rate increased to 26 m^3/min. At 18:15 the wavemaker was started. From 18:15 to 18:30 the device recovered 25 m^3/min of fluid containing 14% free water (3.5 m^3/min) and a 55% water–in–oil emulsion (21.5 m^3/min). At 18:30 the test was stopped and the 19:45 the emulsion was pumped to a holding tank and water pumped to flush the hoses. It is worthy of note that the steam siphon was operated during this cleanup phase and increased the recovery rate initially to 30 m^3/hr from 25 m^3/hr; no samples were taken to determine water contents.

Comparing the pre-and post-Elastol recovery rates for the IPL Sweet crude at similar skimmer operating conditions (1 mm weir immersion and 1 cm weir emersion) and emulsion viscosities (16:23 – 16:50 vs. 18:00 – 18:10 and 15:45 – 16:20 vs. 18:15 to 18:30) indicates that, for the GT-185, the addition of Elastol reduced recovery rates (29 m^3/hr vs. 23 m^3/hr and 30 m^3/hr vs. 25 m^3/hr) and increased the entrainment of water into the skimmer (0 m^3/hr vs. 4 m^3/hr and 2 m^3/hr vs. 4 m^3/hr).

3.2.2.2 Test with Bunker C

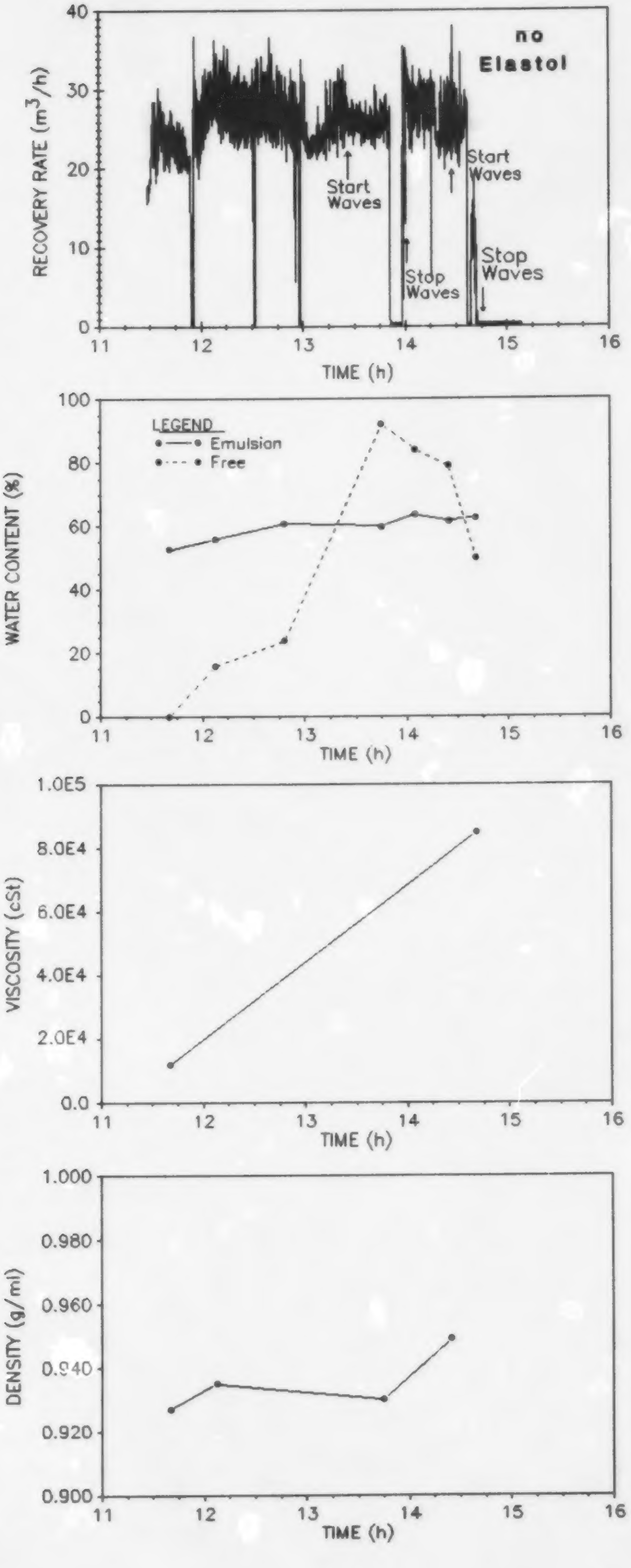
Figure 27 shows the results of the test with GT-185 with Bunker C at a temperature of 18°C. At the start of this test, 5 m^3 of a 50% water-in-Bunker C emulsion was in the test area. The skimmer was again operated with the power-pack operating at full speed (engine speed 2500 rpm; hydraulic valve full open at 50 – 55 bar)

From 11:28 to 11:44 the weir was set at 2 cm below the oil surface (the initial slick thickness was 6.9 cm). Under these conditions the GT-185 recovered about 24 m^3/hr of a 50% water-in-bunker emulsion with a viscosity of 11,700 cSt and no free water. At 11:44 the weir was lowered to 3 cm below the oil surface. At this setting (until 12:04) the recovery rate stayed at about 24 m^3/hr but the recovered fluid contained about 16% free water (4 m^3/hr) and a 56% water-in-bunker emulsion (20 m^3/hr). The weir was further lowered to 4 cm below the oil surface between 12:04 and 12:07 and maintained at this setting until 13:05. The steady-state recovery rate at this condition was 28 m^3/hr including 24% free water (7 m^3/hr) and a 60% water-in-bunker emulsion (21 m^3/hr).

At 13:05 the weir was raised to 3 cm below the oil surface and at 13:10 the steam siphon was started. Raising the weir reduced the recovery rate to the previously measured 24 m^3/hr; introducing the steam siphon into the test section raised this to about 27 m^3/hr. The siphon increased the temperature of the recovered fluid by 22° to 27°C.

FIGURE 27

GT – 185 with Bunker C



At 13:27 the wavemaker was turned on. The wave height increased from 0.42 m at 13:33 to 0.7 m at 13:36 then decreased to 0.57 m at 13:44. In waves, it was noted that the weir periodically flooded. Wave action had little effect on measured recovery rate, averaging about 25 m^3/hr, but at 13:44 in 0.57 m waves with a 4 s period the skimmer was recovering 92% free water. After this, the weir was further lowered to 6 cm below the oil surface with no effect on recovery rate.

At 14:00 the wavemaker was shut off and the skimmer was stopped and lifted from the test area to remove the Light Oil Adapter (Figure 28). At 14:10 the skimmer was replaced in the oil; the weir was set 3 cm below the oil surface. From 14:10 to 14:23 the recovery rate was measured at about 30 m^3/hr, an increase of 5 m^3/hr over similar settings with the Light Oil Adapter in place; however, with the Light Oil Adapter removed the device was recovering about 80% free water (24 m^3/min). By this time, the viscosity of the recovered Bunker C had increased to 90,000 cSt, which may explain some of the dramatic increase in free water recovered though much of the water entrainment is likely due to the difficulty in accurately positioning the weir when the Light Oil Adapter had been removed.

At 14:23 the waves were restarted; this had little effect on recovery rate (staying constant at about 30 m^3/hr) although the wave action seemed to feed more oil to the weir. The free water content of the recovered fluid in 0.4 m waves with a 4 s period was measured at 50% (15 m^3/hr) and the recovered emulsion (15 m^3/hr) contained 63% water. No Elastol was applied for this test. The tests were completed at 14:45 and the Bunker C left in the test area for the next skimmer (Walosep W–2).

3.2.2.3 Test with Terra Nova C–09 Crude

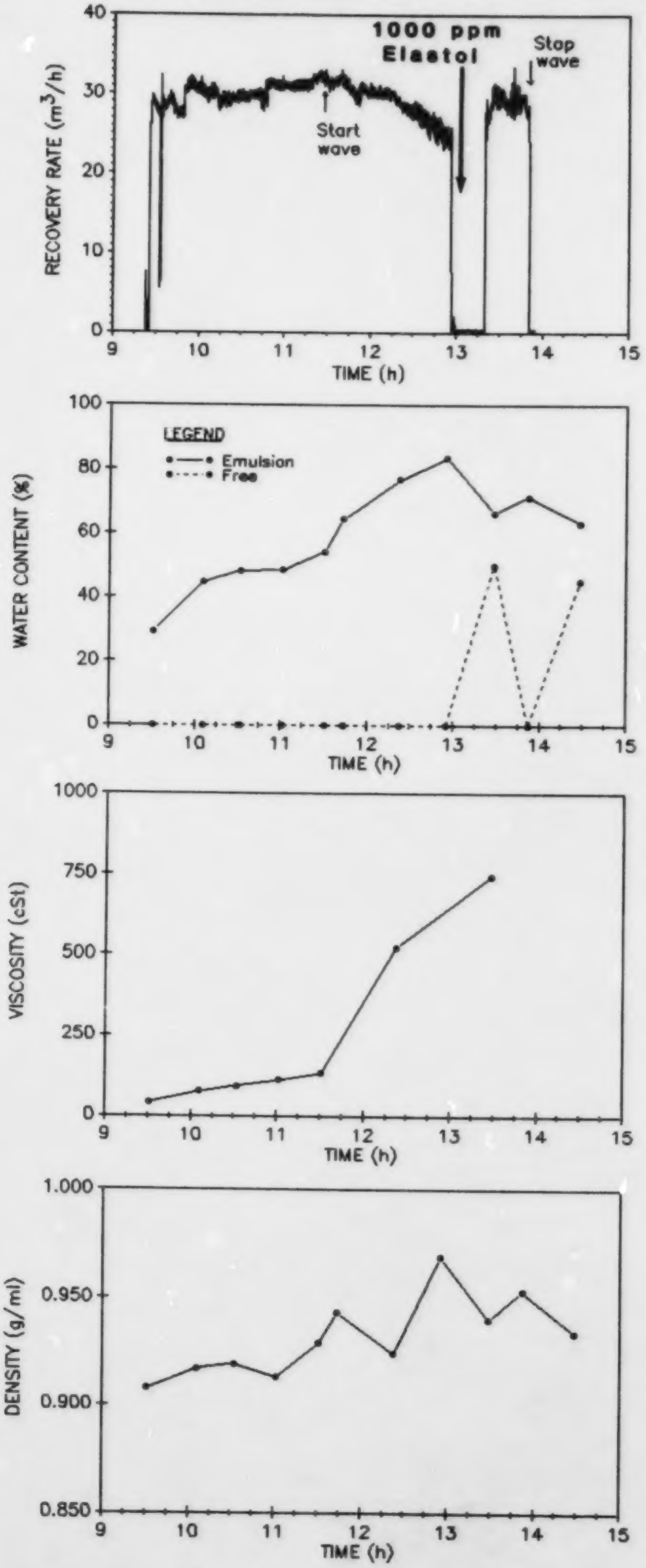
Figure 29 shows the results obtained with the GT–185 (with Light Oil Adapter installed) skimming Terra Nova C–09 crude oil at a water temperature of 12°C. The oil had been placed in the test area the evening before and allowed to weather and cool overnight. The surface of the slick had gelled in the 0°C air by morning.

GT 185
GT 185

Figure 28: GT−185 with light oil adapter removed

FIGURE 29

GT–185 with Terra Nova Crude



At 9:30 the skimmer was started with the power–pack engine set at 2500 rpm and the hydraulic pressure, with the valve only 40% open, reading 70 bar. The surface oil in the test area behaved like ice floes, breaking away from the main body of the slick and moving towards the skimmer (see Figure 15 on page 27). The oil in the lower layer of the slick was in contact with the water (at 12°C) and insulated from the air by the gelled surface oil layer and thus it was fluid and flowed beneath the gelled surface oil and into the skimmer.

From 09:30 to 09:42 the skimmer recovered about 28 m^3/hr of fluid consisting of a 30% water–in–oil emulsion with a viscosity of 42 cSt. About 2.5 m^3/hr of the recovery was entrained water. At 09:42 the hydraulic valve was opened fully and for the remainder of the test the pressure remained in the 50 – 62 bar range. At this point it was noted that the oil in the test area was beginning to fluidize. Between 09:42 and 11:22 the GT–185 recovered oil at a steady 30 m^3/hr. The water entrainment rate over this period was virtually zero. The recovered product was a 50% water–in–oil emulsion with viscosities of 75 cSt @ 10:06, 92 cSt at 10:32 and 110 cSt at 11:01.

At 11:22 the wavemaker was started. By 11:34 in 0.3 m waves it was visually apparent that the skimmer was emulsifying the oil with entrained water. At this point the recovery rate was about 32 m^3/hr of which 2.5 m^3/hr was entrained water and 29.5 m^3/hr was a 50% water–in–oil emulsion with a viscosity of 130 cSt. At 11:44, in 0.45 m waves, the GT–185 was still recovering 32 m^3/hr but the water entrainment rate had increased to about 4 m^3/hr. The recovered emulsion was 65% water. At 11:52 the wave height peaked at 0.78 m; no significant effect on recovery rate was noted and the device followed the 4 s period waves well. From the period 11:47 to 12:23 the wave heights ranged from 0.6 to 0.78 m; over this period the water entrainment rate into the GT–185 averaged about 2.5 m^3/hr. The viscosity of the emulsion at 12:23 was 520 cSt.

From 12:23 to 12:58 the wave height decreased from 0.48 to 0.38 m with a 4 s period. Over this time period the recovery rate declined slowly from 30 m^3/hr to 24 m^3/hr (with an average water entrainment rate of 2 m^3/hr) while the water content of the emulsion increased from 77% to 84%. No viscosity measurements were possible because of the large water drops in the emulsion.

At 13:00 the skimmer was stopped and raised from the test area so that Elastol could be applied. The slick was sprayed with an aqueous slurry of Elastol to give a concentration of Elastol in the oil (as opposed to emulsion) of 1000 ppm. The wave action was continued to mix the Elastol with the emulsion; no other mixing was supplied. At 13:26 the skimmer was lowered and restarted at settings identical to those prior to Elastol addition. The wave height was 0.38 – 0.4 m throughout this portion of the test. At 13:29 the skimmer was recovering 30 m^3/hr consisting of 50% free water (15 m^3/hr) and 50% (15 m^3/hr) emulsion with a water content of 66% and a viscosity of 745 cSt. In earlier offshore tests (S.L. Ross 1988) the GT–185 is reported to have recovered Elastol–treated waxy oil emulsion (5600 cSt) with no free water at a rate of 19 m^3/hr in waves of about 1 m height.

At 13:45 the waves were shut off while maintaining the skimmer settings. At 13:52 the skimmer was recovering about 28 m^3/min of fluid containing no free water and a 71% water–in–oil emulsion. No viscosity determination was possible.

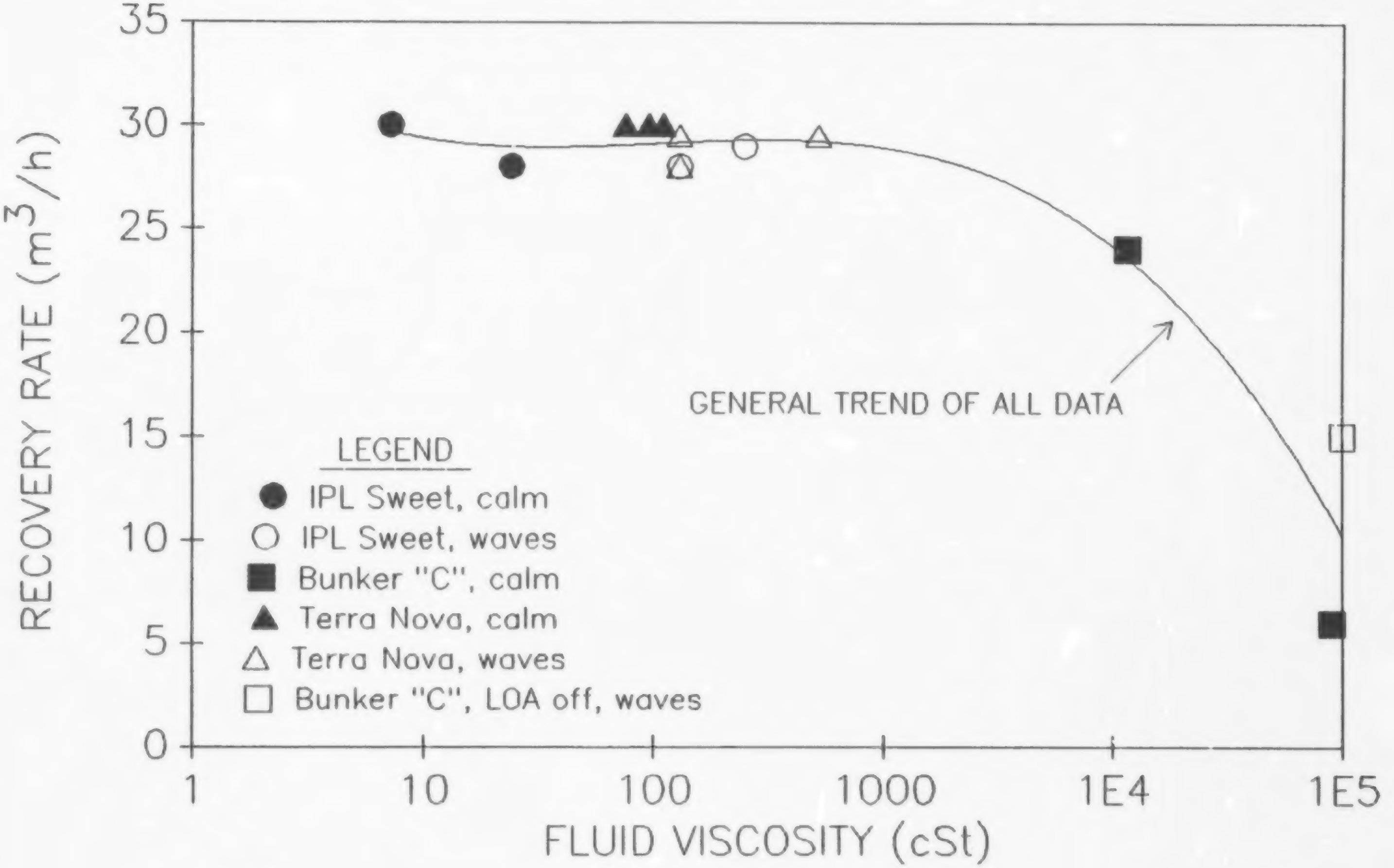
Comparison of pre– and post–Elastol test results with similar skimmer settings, emulsion viscosities and waves (10:49 – 11:22 vs. 13:45 – 13:55 and 12:23 – 12:55 and 13:26 – 13:45) shows that the recovery rates (30 m^3/min with no water entrainment vs. 28 m^3/hr with 2 m^3/hr water entrainment and 30 m^3/hr with 15 m^3/hr water entrainment) were not improved by Elastol addition and water entrainment by the skimmer was increased by Elastol treatment.

3.2.2.4 Comparison

Figure 30 shows the effect of fluid viscosity and waves on the oil/emulsion recovery rate (corrected for water entrainment) of the GT–185 skimmer. The device performed well, showing very little sensitivity to oil viscosity up to about 12,000 cSt. The oil/emulsion recovery rate decreased dramatically at viscosities in the 100,000 cSt range. Although not reflected in the recovery rate results, visual observations indicate that, with a completely gelled waxy oil, the skimmers performance would be much poorer than reported here, likely in the range of the results at 100,000 cSt viscosity.

FIGURE 30

RECOVERY RATE vs VISCOSITY
GT – 185



Oil content factors were consistently in the 90+% range for the crude oils in both calm conditions and waves. Addition of Elastol reduced these factors to the 50 – 80% range. In the test with Bunker C the oil content factor was 75 – 83% in calm conditions and 8% in waves; removal of the Light Oil Adapter (LOA) may have been responsible for a drop in oil content factor to 20 – 50% in calm conditions.

Removal of the LOA, though recommended by the manufacturer for oils with viscosities over 15,000 cSt, is not recommended for skimming operations in waves; the presence of the bellows–like adapter improves the wave–following of the weir and thus reduces water entrainment.

In general the skimmer proved reliable and sturdy, and followed the waves well. Consideration should be given to improving the weir adjustment lever on the power–pack to allow more precise control of the weir position.

3.2.3 Heavy Oil Skimmer

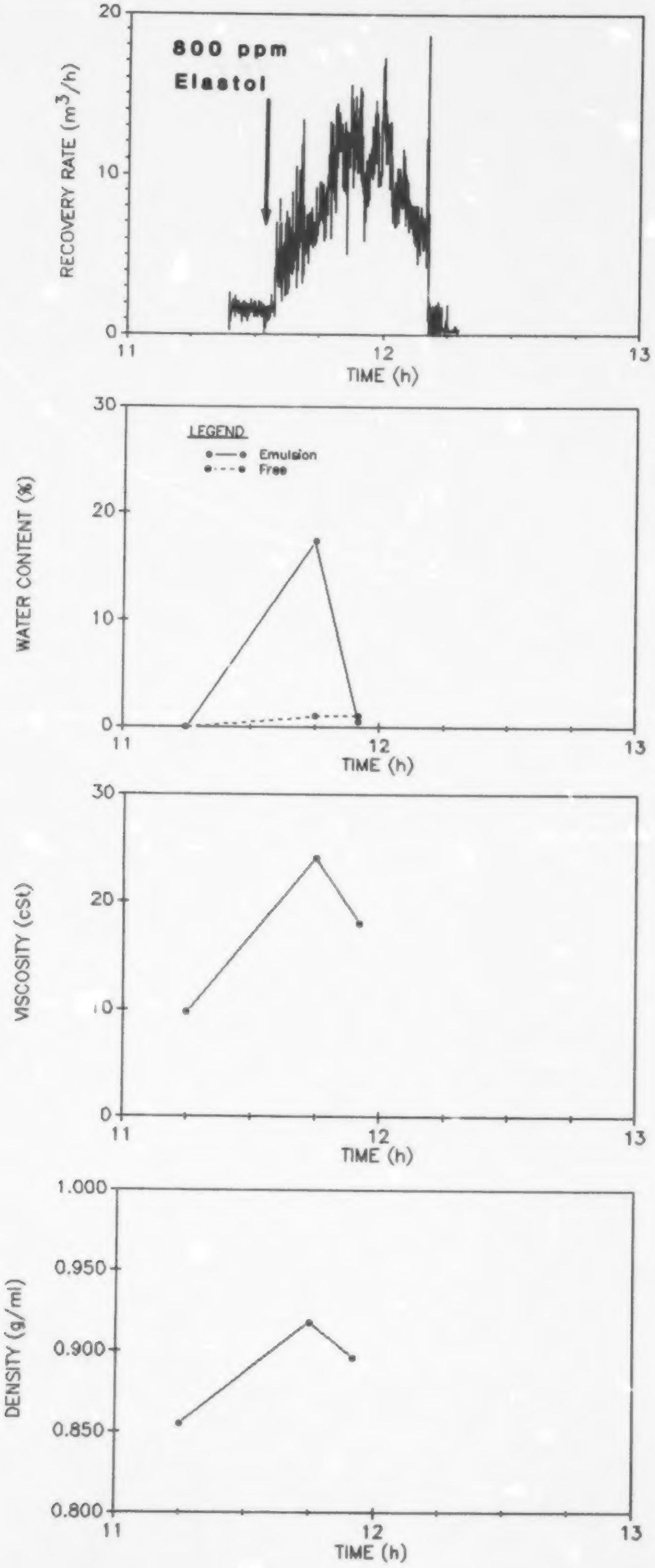
3.2.3.1 Test with IPL Sweet Crude

Figure 31 shows the results obtained with the Heavy Oil Skimmer in IPL Sweet crude at a temperature of 16.5°C.

The Heavy Oil Skimmer (Figure 32) was placed in the test slick at 09:53. The drums were started and set at 15 rpm in the upward direction (upward being defined as the drum surface moving up through the oil, drawing oil over the top of the drum and down to the scraper; downward being the reverse, i.e., the drum moves down through the oil, drawing oil beneath the water, under the drum and up to the scraper). The skimmer was operated in the upward mode at various drum speeds for 25 minutes; no recovery was measured and visual observation of the drum indicated that very little, if any, oil was adhering to the drum surface. At 10:57 Elastol was applied as an aqueous slurry to oil in the test area; the wavemaker was turned on for 18 minutes to mix the Elastol with the oil. At 11:33 the skimmer was restarted.

FIGURE 31

Heavy Oil Skimmer with IPL



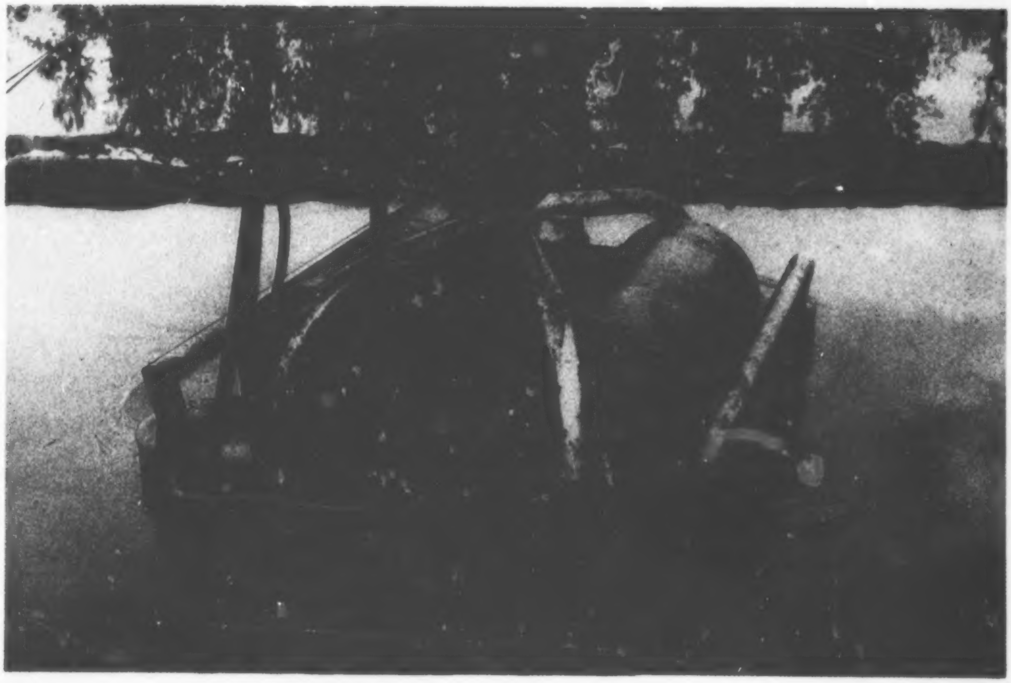


Figure 32: Heavy oil skimmer operating in IPL sweet crude

At 11:35, with a drum rotation of 15 rpm upward and the hydraulic pressure to the pump set at 40 bar, the device recovered about 5 m^3/hr of oil with a viscosity of about 24 cSt and a small amount of free water. The emulsion water content was 17%.

At 11:41 the drum rotational speed was reduced to 10 rpm, then further reduced to 7.5 rpm at 11:59. The first reduction increased the recovery rate to about 12 m^3/hr of a water–free oil with a viscosity of 18 cSt. The second reduction lowered the recovery rate somewhat, to about 8–10 m^3/hr. At 12:04 the drum speed was increased to 15 rpm, with a resultant decrease in recovery rate to about 6 m^3/hr. At 12:08 the drum rotation was reversed to downwards; no oil was observed to be entering the sump and the measured oil recovery rate was zero. The test was stopped and the oil in the test area pumped to a holding tank using the Walosep W–2 skimmer.

3.2.3.2 Test with Bunker C

Figure 33 shows the results of the test of the Heavy Oil Skimmer with Bunker C at 17°C. No recovered fluid samples were collected. The Bunker C in the test area was that left from the previous day's test of the Walosep W–2 and consisted of a 70% water–in–bunker emulsion with a viscosity exceeding 100,000 cSt.

The skimmer was placed in the test area and started at 13:18. Despite running the drums in the upward and downward modes at various speeds and immersion depths, no oil was recovered. While operating in the upward mode, the oil in direct contact with the drums adhered to the drum for perhaps ¼ of a rotation, after which time a flow of water, generated by the action of the drum rising out of the water at an acute angle to the water surface, forced the oil away from the drum (Figure 34) preventing its collection. When the drums were operated in the downward mode, oil was rapidly drawn below the water surface by the drums. This oil adhered to the drum and was drawn up to the scraper where it was removed; however, because of the location of the hopper lip the Bunker C did not enter the hopper but fell back and built up beneath the pump until such a thickness (15 – 20 cm) was developed that it flowed back out past the drum.

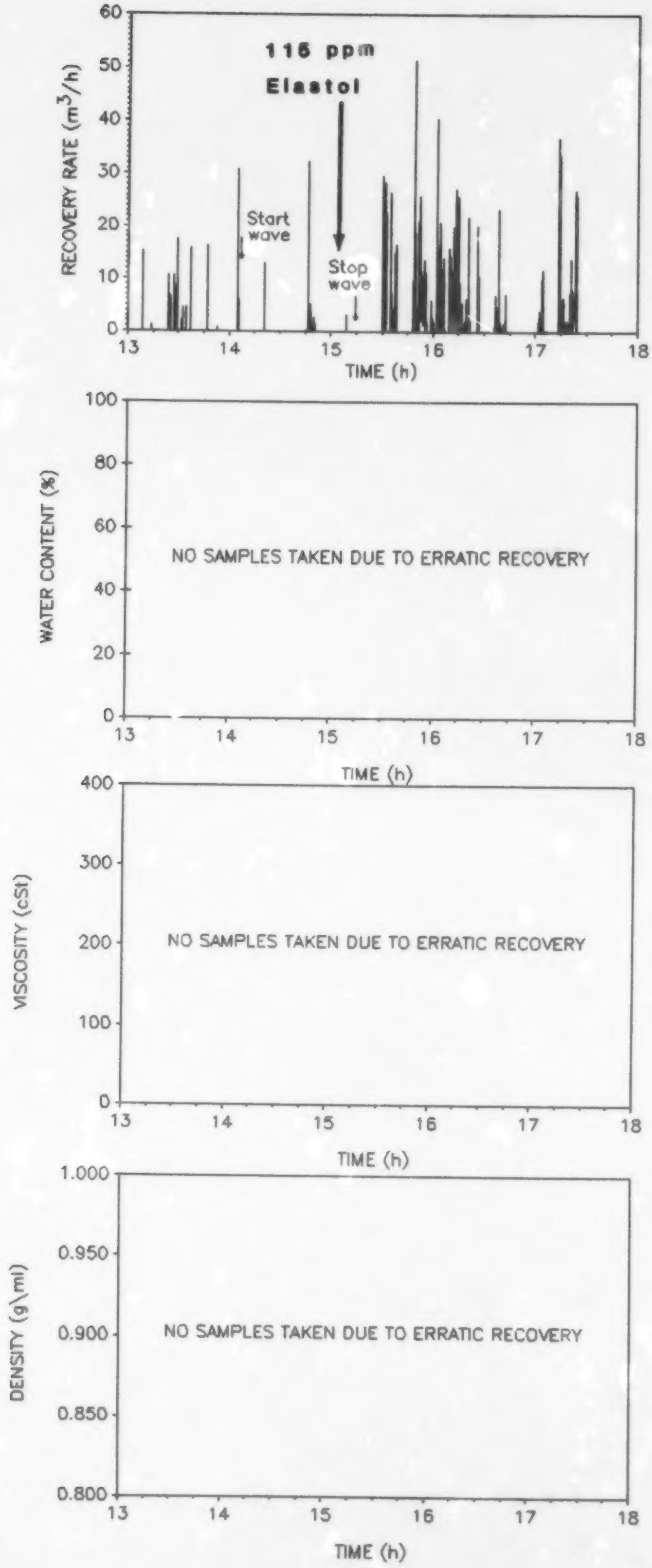


FIGURE 33

Heavy Oil Skimmer with BUNKER C

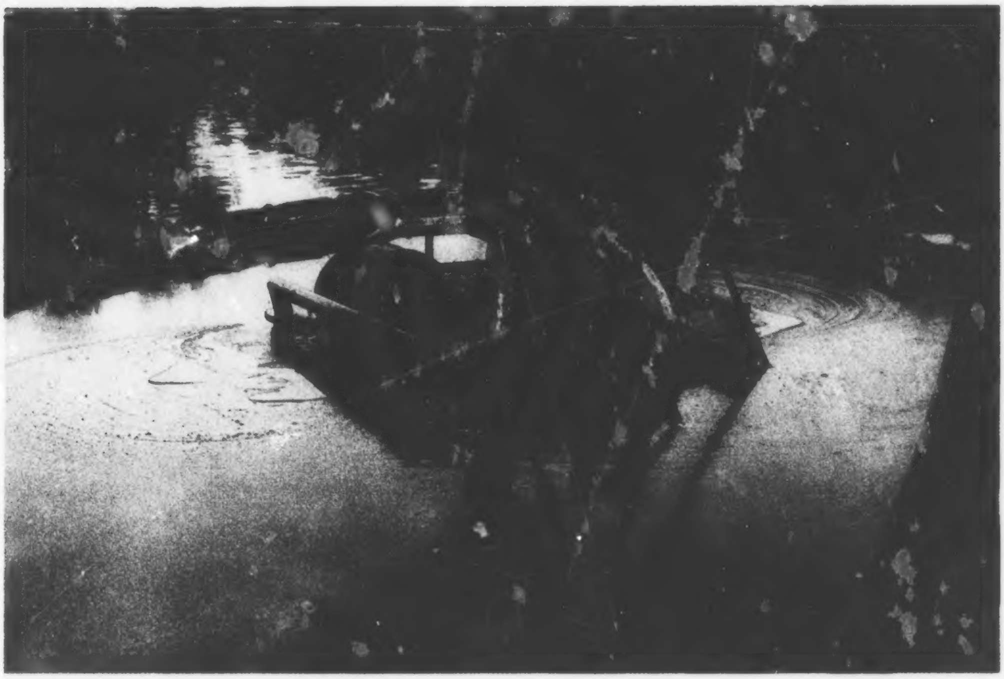


Figure 34: Heavy oil skimmer operating in Bunker C in upward rotation mode

From 14:07 to 15:15 the wavemaker was operated to determine if wave action would permit better recovery; no recovery was noted in either the upward or downward drum rotation mode. The skimmer was allowed to "free float", connected to the Framo hydraulic arm only by a 2 m length of wire rope. Allowed this freedom, it followed the waves well, without excessive pitch and roll.

At 15:15 Elastol was added to the Bunker C emulsion as a slurry in 130 l of diesel fuel. The Elastol concentration in Bunker C was 115 ppm.

By 15:45 the Heavy Oil Skimmer began to recover some Bunker C while operating in the upward rotation mode. The recovery rate was erratic but amounted to some 5 m^3/hr. At 15:53 the drum speed was increased to 30 rpm, with little effect on recovery rate. After this the device was used to recover the Bunker C from the test area by alternating between upward and downward modes. First the drums would be rotated downward to draw in a thick slick of Bunker C beneath the skimmer, then the drums would be rotated upwards to carry as much of this oil as possible over the top of the drum to the scrapers. In this mode the recovery rate varied between 5 and 10 m^3/hr.

3.2.3.3 Test with Terra Nova C–09 Crude

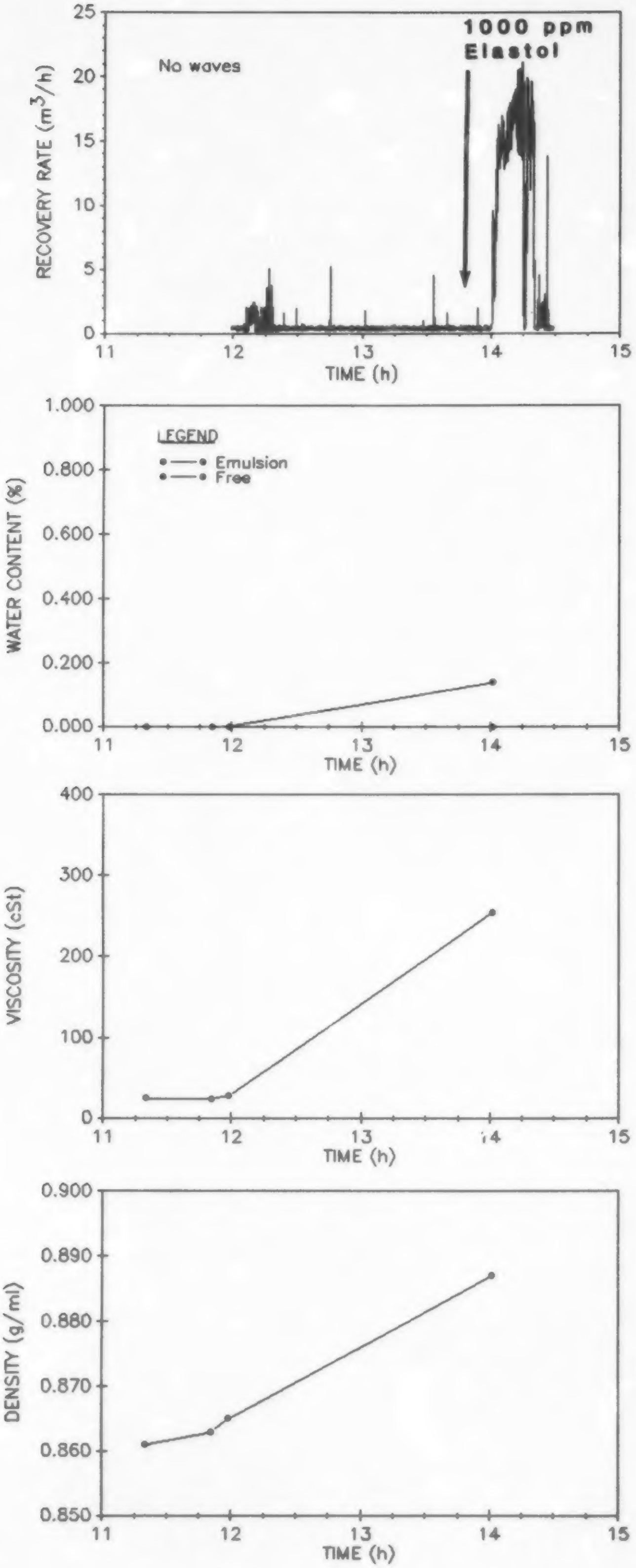
Figure 35 shows the results for the test of the Heavy Oil Skimmer with Terra Nova C–09 crude oil at a temperature of 15°C (well above the oil's pour point).

At 10:51 the skimmer was started, but the oil had not cooled sufficiently (36°C) to adhere to the skimmer drums. At 11:20 the wavemaker was started to assist in cooling the oil; by 11:45 the oil temperature had dropped to 19°C and the wavemaker was shut off.

At 11:58 the skimmer was started with a drum speed of 15 rpm upward and the pump hydraulic pressure set at 30 bar. From 11:58 to 12:15 the device recovered oil at a rate of 1–2 m^3/hr. The recovered oil contained no water and had a viscosity of 27 cSt. The skimmer was stopped at 12:15 and the wavemaker turned on from 12:22 to 12:40 to further weather the oil.

FIGURE 36

Heavy Oil Skimmer with TERRA NOVA Crude



At 12:45 the skimmer was run with the drums rotating upward at 13 rpm; no recovery was observed or measured and the skimmer was stopped at 13:00. At 13:45 an aqueous slurry of Elastol was sprayed on the slick, to give a concentration of 1000 ppm Elastol in the oil.

At 13:59 the skimmer was restarted with the drums rotating upward at 13 rpm. From 13:59 to 14:13 the Heavy Oil Skimmer recovered about 15 m^3/hr of oil, containing 0.2% emulsified water, with a viscosity of 255 cSt.

At 14:13 the drum rotation was reversed to downward. This had little effect on the recovery rate and at 14:20 the test was stopped. The Walosep W–2 skimmer was used to pump the Elastolized Terra Nova C–09 crude to the holding tank.

In previous offshore tests with a waxy oil emulsion (S.L. Ross 1987) the Heavy Oil Skimmer failed to recover untreated oil but, once treated with Elastol, recovered emulsion at a rate of 11 m^3/hr in waves of about 1 m with one drum damaged. The viscosity of the emulsion was in the range 1900–5600 cSt.

3.2.3.4 Comparison

In general, the Heavy Oil Skimmer performed poorly in the tests, proving unable to recover any of the test oils unless Elastol had been added to increase their adherence to the drum material and their cohesiveness.

It is worthy of note that the drums, when rotated in the downward mode, drew in a considerable thickness of the viscous oils beneath the skimmer; modifications to the device could be made to take advantage of this phenomenon in improving the skimmer's performance.

In waves, the skimmer proved stable and followed the waves well; operating the device in the free–floating mode, rather than hard–mounted to the Framo hydraulic arm, was a definite advantage. During operation of the skimmer, it was noted that the scraper blade abraded the absorbent material on the drums. Mounting the scrapers with a spring–loaded adjusting system would allow the scraper to accommodate the out-of-round portions of the drums better than the double-nut system presently used.

3.2.4 Walosep W-2

3.2.4.1 Test with IPL Sweet

Figure 36 shows the results of the test of the Walosep W-2 skimmer with IPL Sweet crude oil at a temperature of 15°C. The skimmer was powered by the GT-185 diesel/hydraulic power-pack; this power-pack did not provide sufficient hydraulic pressure to drive the skimmer at its full capacity.

At 09:17 the skimmer was placed in the oil and started (Figure 37); the skimmer settings were: rotor speed at 12 - 13 rpm, weir at 5 cm below the oil surface and pump at 3½ (out of a possible 10). The device was operated at these settings throughout the tests.

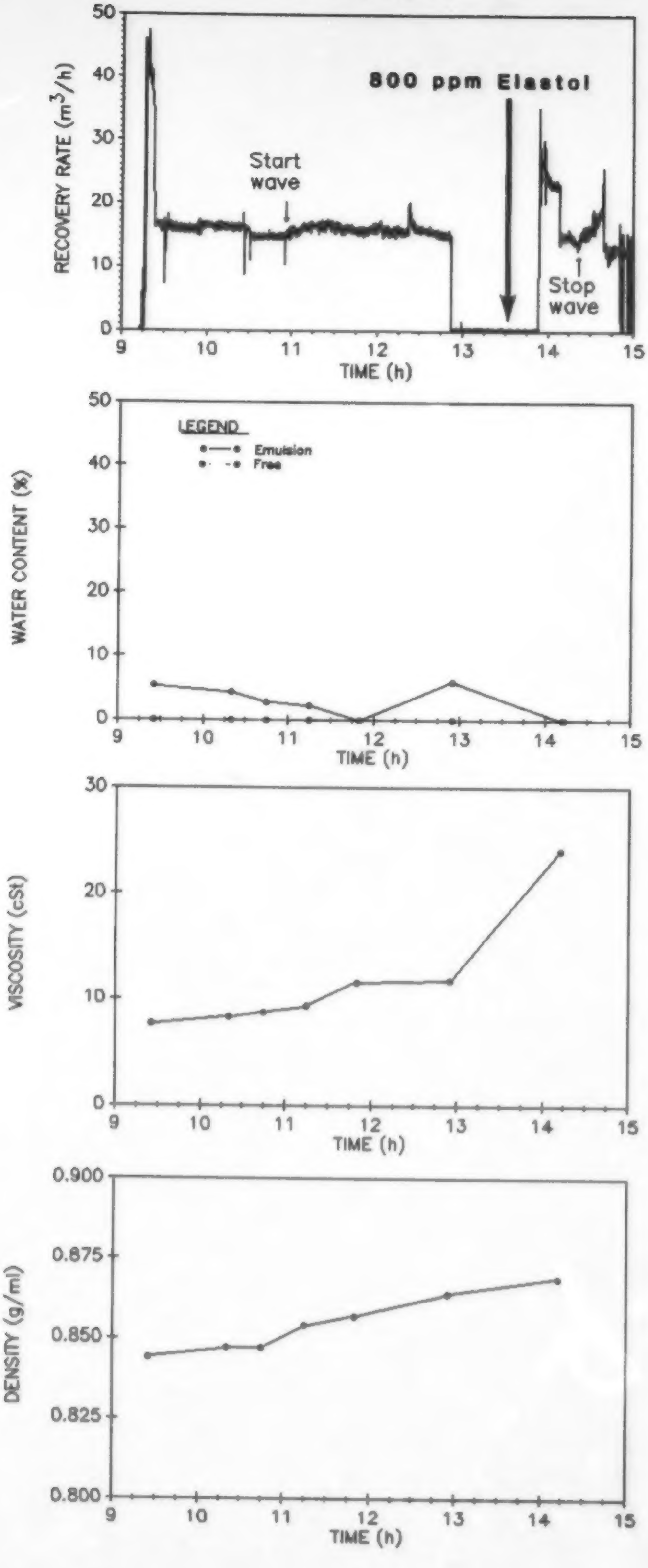
From 09:22 to 10:45 the skimmer recovered oil steadily at a rate of 16 m^3 hr. No free water and less than 5% emulsified water was recovered. During this period the viscosity of the oil increased very little, from 7.7 cSt to 8.7 cSt.

At 11:05 the wavemaker was started; this had no measurable effect on the skimmers performance. From 11:05 to 12:59 the Walosep W-2 continued to recover virtually water-free oil at a rate of 16 m^3/hr. The device, in waves with heights ranging from 0.3 to 0.8 m and 4 s periods, followed the water surface very well. The viscosity of the oil increased from 9.3 to 11.8 cSt over this time period.

At 12:59 the skimmer was stopped and raised out of the water. At about 13:30 an aqueous slurry of Elastol was applied to the oil. The concentration of Elastol in the oil was 800 ppm. Wave action was used to mix the Elastol with the oil for 30 minutes.

FIGURE 36

Walosep with IPL



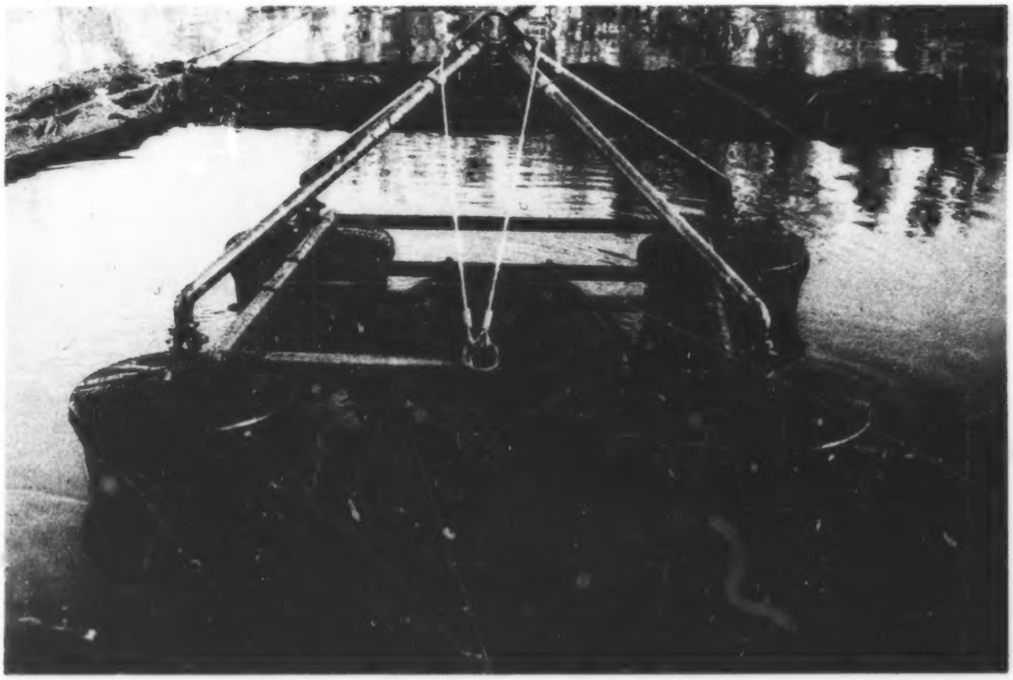


Figure 37: Walosep W–2 skimmer operating in IPL Sweet crude oil

At 14:00 the skimmer was restarted and from 14:03 to 14:12 operated at the settings previously used. Over this period the device recovered Elastol–treated oil at a rate of 24 m^3/hr with no water and a viscosity of 24 cSt; however, the pump was labouring and its speed was reduced to 2 3/4 at 14:42. This adjustment reduced the recovery rate to the previously measured 16 m^3/hr. At 14:20 the wavemaker was shut off and the oil pumped to the holding tank. It is interesting to note that, as the slick thickness decreased during this operation, the recovery rate increased (to 19 m^3/hr); no samples were taken during this time.

Comparing pre–Elastol with post–Elastol recovery results indicates that Elastol addition improved the recovery rate of the Walosep W–2 by some 40% at similar skimmer settings. The addition of Elastol, however, put an additional load on the skimmer pump.

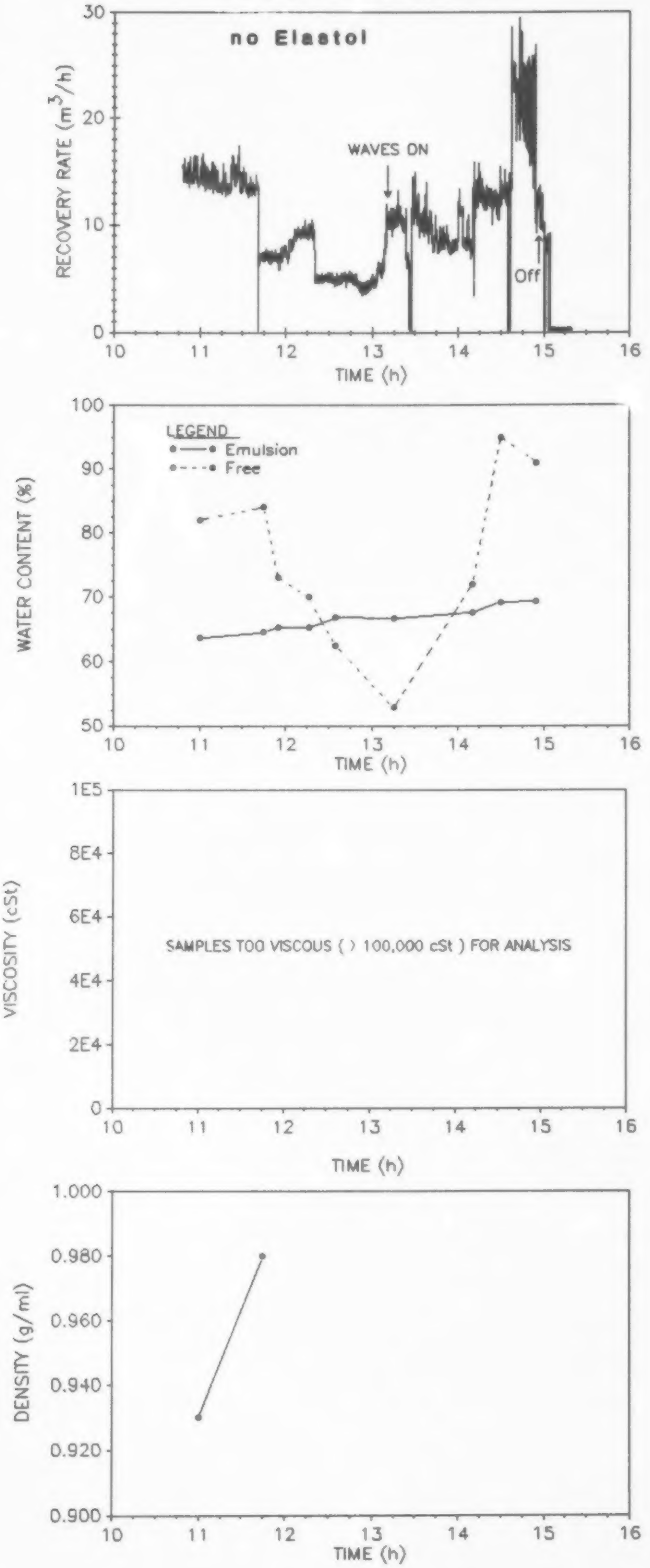
3.2.4.2 Test with Bunker C

Figure 38 shows the results of the test of the Walosep W–2 skimmer with Bunker C at a temperature of 17°C. Since the Bunker C had been left in the test area from the previous day's tests (with the GT–185) it was initially emulsified to a water content of 64%; the samples were too viscous (in excess of 100,000 cSt) for measurement.

From 10:48 to 11:47 the skimmer was operated with a rotor speed of 12 – 13 rpm, the weir set 5 cm below the oil surface and a pump setting of 3½ (Figure 39). The device recovered 14 m^3/hr of a mixture of 83% free water (12 m^3/hr) and a 64% water–in–bunker emulsion (2 m^3/hr).

FIGURE 38

WALOSEP W-2 with BUNKER C



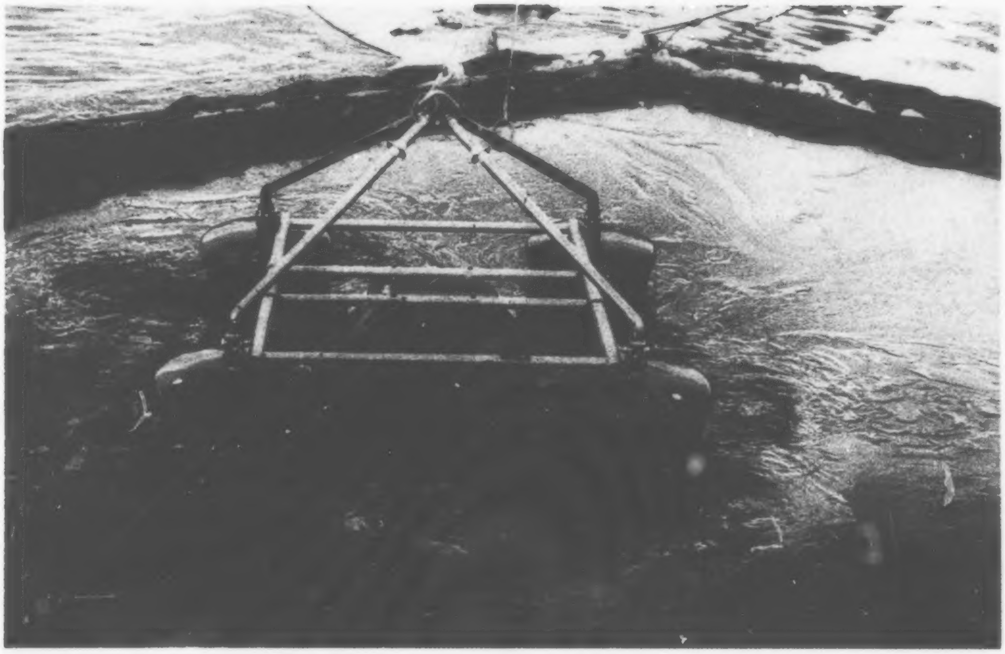


Figure 39: Walosep W–2 operating in emulsified Bunker C

At 11:42 the rotor speed was increased to 16 rpm and the pump speed reduced to a setting of 2½. This had the effect of reducing the recovery rate to 7 m^3/hr and decreasing the free water to 73% (5 m^3/hr); the emulsion recovery rate was constant at 2 m^3/hr. At 12:00 the rotor speed was reduced back to 12 – 13 rpm and maintained at this speed for the remainder of the test. From 12:00 to 12:20 the recovery rate increased to 9 m^3/hr with 70% free water (6 m^3/hr) and a 56% water–in–bunker emulsion (3 m^3/hr). At 12:20 the pump speed was further reduced to a setting of 2. From 12:20 to 13:00 the skimmer recovered fluid at a rate of 5 m^3/hr consisting of 62% free water (3 m^3/hr) and a 67% water–in–bunker emulsion (2 m^3/hr).

At 13:00 the wave maker was started. Between 13:00 and 13:30 the wave heights increased from 0.3 m initially to 0.73 m at 13:15 and then decreased to 0.5 m by 13:30. During this period the Walosep W–2 recovered fluid at an average rate of 10 m^3/hr. The recovered fluid contained 53% free water (5 m^3/hr) and a 67% water–in–bunker emulsion 5 m^3/hr) at 13:15. The action of the waves seemed to improve the flow of oil to the skimmer. At 13:30 the pump setting was increased to 2½ after some adjustments. From 13:30 to 14:00 this setting was maintained in waves of 0.44 m to 0.5 m high. The recovery rate was measured at 12 m^3/hr initially but decreased slowly to about 8 m^3/hr by 14:00.

At about 14:01 the pump speed was further increased to a setting of 3. Although this initially increased the recovery rate to 12 m^3/hr, the pump was labouring and the pump setting was reduced to 2½ and then increased slightly to 2 3/4 at 14:25. At this point the Bunker C emulsion in the test area had broken up into a series of discrete chunks which were being drawn into the skimmer by the action of the rotor. From 14:25 to 14:55 the wave height increased from 0.45 m to 0.68 m. At this latter height the device was recovering 20 m^3/hr of a mixture of 90% free water (18 m^3/hr) and a 70% water–in–bunker emulsion (2 m^3/hr).

It seems that, regardless of skimmer settings or wave height, the device was capable of recovering only 2 to 5 m^3/hr of the very viscous Bunker C emulsion. Optimizing skimmer settings only reduced the amount of free water collected by the device. No Elastol was used for this test.

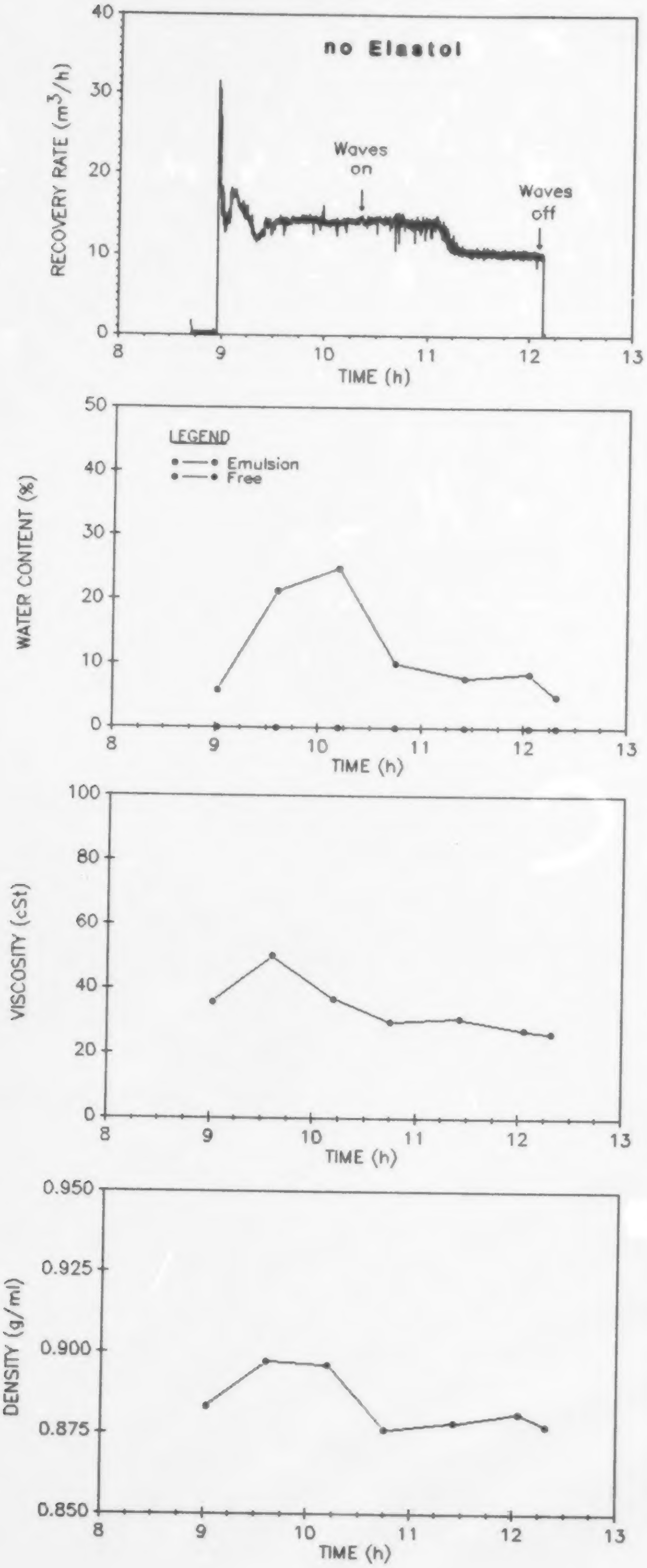
3.2.4.3 Test with Terra Nova C–09 Crude

Figure 40 shows the results of the test of the Walosep W–2 with Terra Nova C–09 crude oil at a water temperature of 15°C. The oil had been placed in the test area the previous evening to allow it to cool, weather and gel. The air temperature at the start of the test was 5°C, thus the surface of the oil had gelled. The skimmer's rotor speed was set at 12 – 13 rpm, the weir was submerged 5 cm below the oil surface and the pump was set at 2½ (the highest possible with this oil) for the duration of this test.

At 08:55 the skimmer was placed in the oil (Figure 41) and by 08:58 was operating. The gelled surface oil resembled a number of individual ice floes that were slowly drawn into the skimmer by the action of the rotors on the fluid oil underneath. From 08:58 to 09:03 the recovery rate increased from 14 m^3/hr to 17 m^3/hr and consisted of a 6% water–in–oil emulsion with a viscosity of 36 cSt. By 09:03 the recovered oil was flowing from the spill plate in a channel back to the skimmer. Repositioning the skimmer stopped this effect for only a short time. From 09:03 to 09:10 the recovery rate declined from 17 m^3/hr to 12 m^3/hr. From 09:10 to 09:30 the recovery rate increased to 14 m^3/hr. The viscosity of the recovered fluid at this time had increased to 50 cSt (this represents the viscosity of the waxy oil after being sheared). The water entrainment rate during this period (09:00 – 09:36) was about 0.3 m^3/hr. forming an emulsion containing 21% water. From 09:30 to 10:20 the recovery rate remained constant at 14 m^3/hr. The water content of the emulsion increased only slightly to 25%, indicating little entrainment of water by the skimmer. During this period the viscosity of the oil declined from 50 to 37 cSt and it was visually apparent that the oil was warming and fluidizing (the sun came out at 10:15 which accelerated the oil fluidizing).

FIGURE 40

Walosep with Terra Nova crude



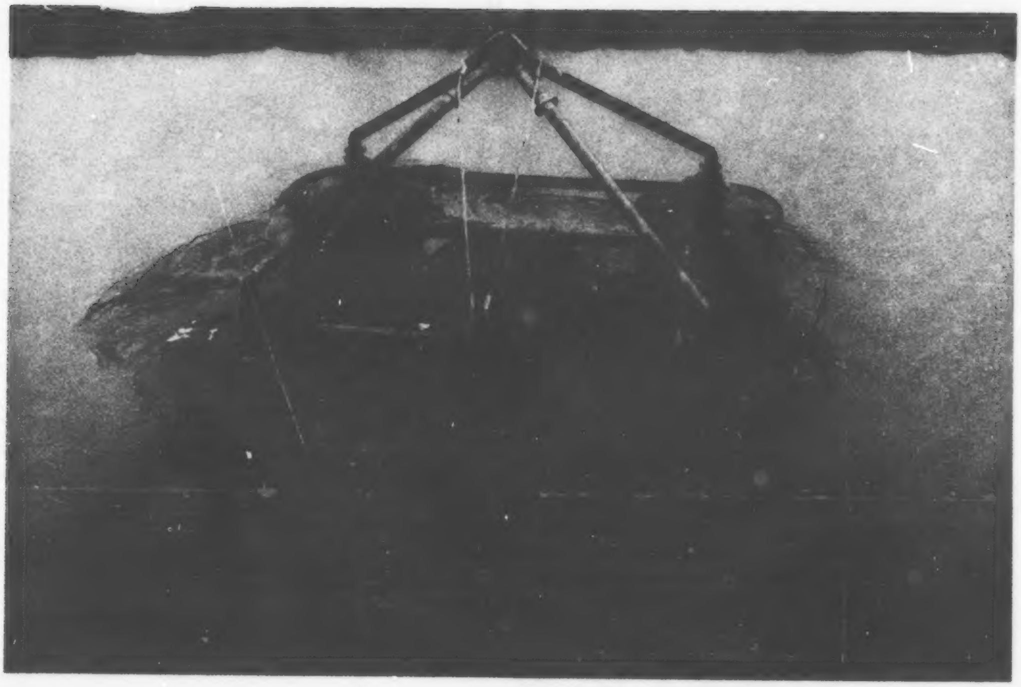


Figure 41: Walosep W–2 in Terra Nova C–09 crude oil

At 10:20 the wavemaker was turned on. The waves (building initially to 0.71 m high by 10:39 then declining to a steady 0.4 – 0.5 m by 10:55) mixed the oil in the test area, causing it to completely fluidize (with a viscosity of 26 – 30 cSt) and reducing the emulsion water content of the recovered oil to 7 – 10%. From 10:20 to 11:05 the recovery rate was a steady 14 m^3/hr with no measurable water entrainment. At 11:05 the recovery rate inexplicably slowed to about 11 m^3/hr and then slowly declined to about 10 m^3/hr over the period 11:15 to 12:03 when the wavemaker was shut off. This decrease in recovery rate may be due to unregistered changes in the power–pack or skimmer settings or due to increases in the oil viscosity in the test area that did not show up once the oil had been sheared by the skimmer pump. At 12:07 the test was stopped.

Comparison of the results for the Walosep W–2 skimmer for the conventional crude vs. the waxy crude show that the device collected 12 cSt IPL Sweet crude in waves at a rate of 16 m^3/hr with a pump setting of 3½ and collected 30 cSt Terra nova crude at a rate of 14 m^3/hr at a pump setting of 2½. No significant difference is attributable to the waxy oil at the temperature of these tests (15°C).

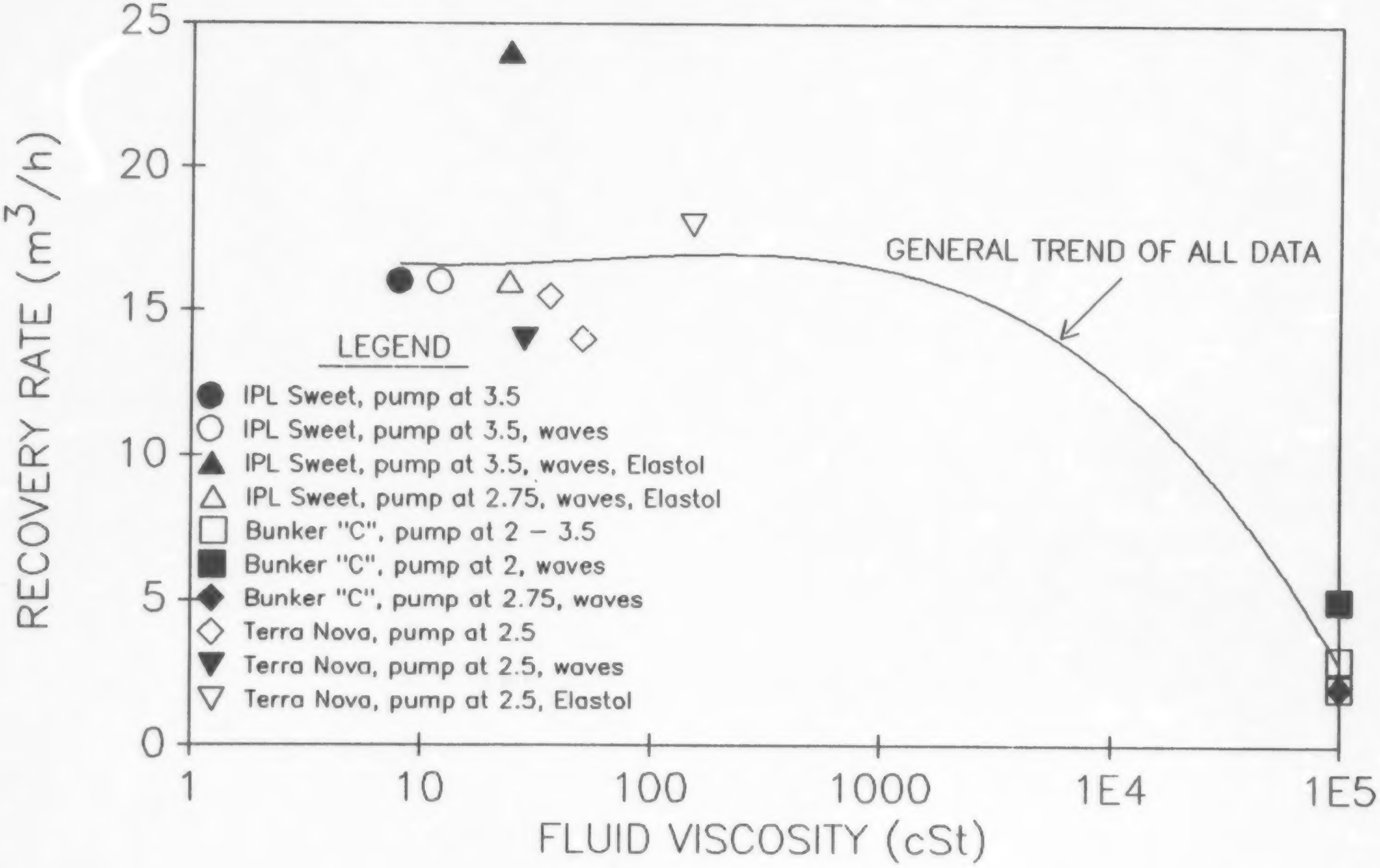
No Elastol was applied for this test, since the Walosep W–2 had been used to recover Elastolized Terra Nova C–09 crude after the unsuccessful test of the Heavy Oil Skimmer with this oil. Those results indicated an average recovery rate of 18 m^3/hr of an Elastolized 8% water–in–oil emulsion with a viscosity of 87 – 220 cSt at a water temperature of 15°C. This represents a 30% improvement in recovery rate in total, with 15% (2 m^3/min) attributable to a higher pump setting (3½ vs. 2½) and 15% (2 m^3/min) attributable to Elastol.

3.2.4.4 Comparison

Figure 42 shows the recovery rate of the Walosep W–2 as a function of viscosity. The general trend is that, in the range up to several hundred cSt, the recovery rate is not a function of viscosity. As the viscosity increases to 100,000 cSt the recovery rate declines to 2 – 5 m^3/hr. It must be remembered that this data represents the recovery rate of the skimmer with the pump set at a maximum of only 3½ on a scale of 10. The most impressive feature of the Walosep W–2 is its ability to collect pure,

FIGURE 42

RECOVERY RATE vs VISCOSITY
WALOSEP W-2



unemulsified oil due to the combined action of the rotor and the pump location. Throughout the tests, even in waves up to 0.7 m, the device entrained virtually no water when skimming crude oil (oil content factors were consistently in the 98+% range); only when operating in very viscous Bunker C did the device collect water (oil content factors ranging from 17 to 47%). Another advantageous feature of this skimmer is its ability to draw in discrete chunks of viscous, gelled oil by the action of the rotor.

The skimmer operated without difficulty during its test series, though it was underpowered by the GT–185 power–pack. The device followed the waves very well. One minor disadvantage of the device was the need to manually set the weir height, although this was only necessary during its initial deployment.

Application of Elastol to the test crude oils did improve the Walosep W–2's recovery performance by 15 to 40%, although the increased viscosity of the oil caused the underpowered pump to labour, necessitating reductions in pump speed and throughput.

3.3 Summary

3.3.1 Recovery Rate and Oil Content Factor

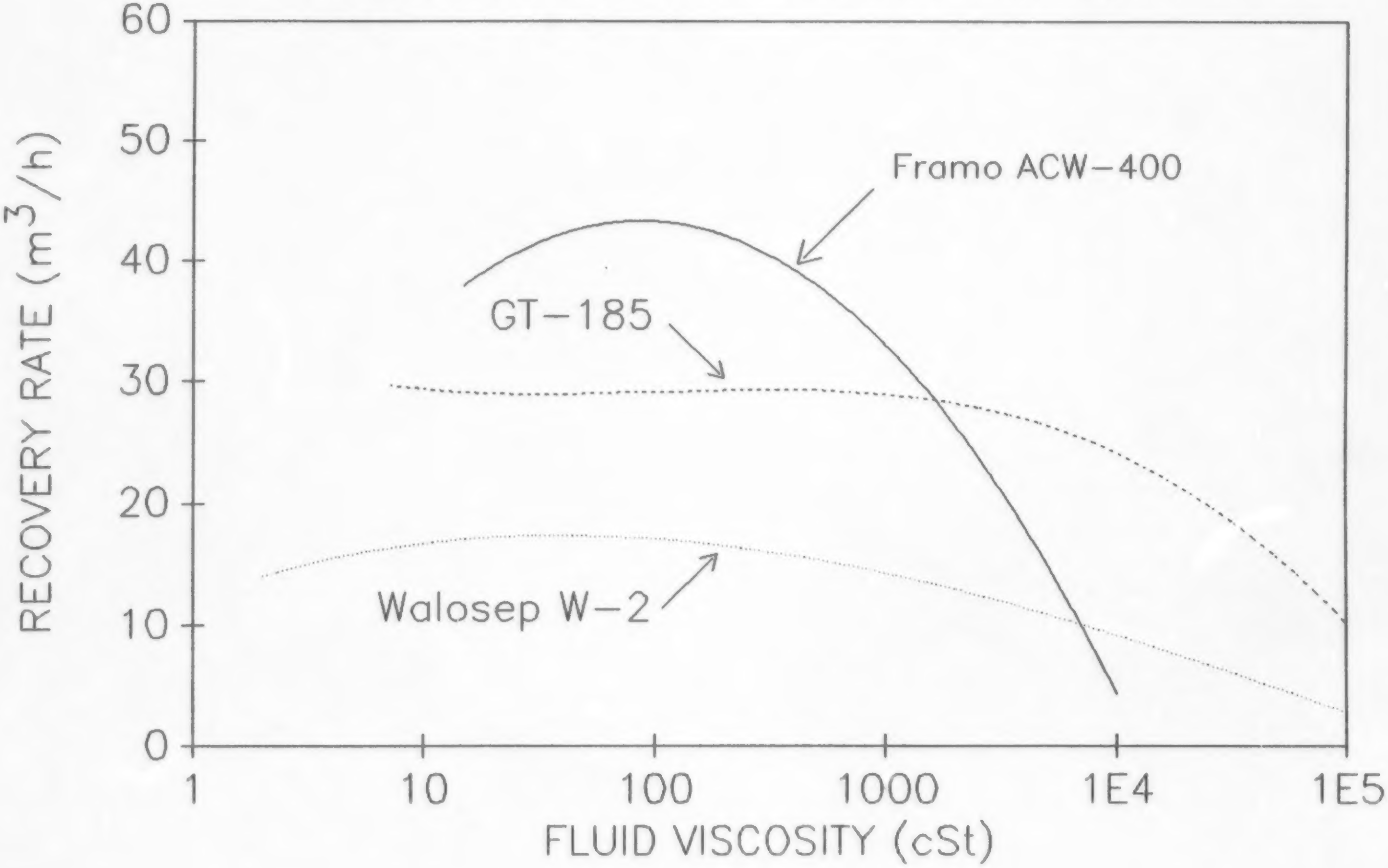
Figure 43 shows a comparison of the general trend in oil/emulsion recovery rate as a function of viscosity for the Framo ACW–400, GT–185 and Walosep W–2 skimmers.

The Framo ACW–400 had the highest measured oil/emulsion recovery rates (35–45 m^3/hr) for oils or emulsions with viscosities less than about 1000 cSt. Oil/emulsion content factors varied from 88 to 97% in this range. With oil viscosities in the 10,000 cSt range, oil/emulsion recovery rates fell to 5–10 m^3/hr with oil/emulsion content factors in the 75 to 88% range.

FIGURE 43

RECOVERY RATE COMPARISON

Framo ACW-400, GT-185 and Walosep W-2



Optimum results for oil/emulsion recovery rate with the Framo ACW–400 were 53 m^3/hr of IPL Sweet crude in calm conditions at a disc speed of 17 rpm and the weir set 5 cm below the oil surface; optimum results for oil/emulsion content factor were 98% with IPL Sweet crude in calm conditions with the weir fully raised and a disc speed of 15 rpm. The action of the skimmer head in waves of 0.4–0.5 m and greater with 4 s periods seriously impairs the device's capabilities.

The GT–185's performance was unaffected by oil viscosity or wave action (in the 0.4–0.6 m high range with a 4s period) recovering a steady 25–30 m^3/hr of oil or emulsion over the range 10–10,000 cSt. At a viscosity of 100,000 cSt recovery rates declined to about 10 m^3/hr. Oil/emulsion content factors were consistently 90+% with viscosities up to 1000 cSt, declining to 83% for Bunker C (10,000 cSt) in calm conditions and 8% for emulsified Bunker C (100,000 cSt). Wave action greatly reduced oil content factors when skimming Bunker C, as did removal of the Light Oil Adapter.

Optimum results for oil/emulsion recovery rate with the GT–185 were 30 m^3/hr with fresh crude in calm conditions and the Light Oil Adapter weir set 2 cm below the oil surface. The optimum oil content factor was 99+%, obtained under the same conditions.

The Walosep W–2 skimmer, despite being underpowered, consistently recovered 14–16 m^3/hr of oil or emulsion over a viscosity range of 10–200 cSt. With viscosities in excess of 100,000 cSt recovery rates declined to the 2–5 m^3/hr range. Oil/emulsion content factors exceeded 98% in the viscosity range 10–200 cSt, even in wave action; oil/emulsion content factors while skimming viscous Bunker C emulsions declined to 17–47%.

Optimum oil/emulsion recovery rates (16 m^3/hr) were obtained with the Walosep W–2 with fresh IPL Sweet crude in both calm conditions and waves. Optimum oil/emulsion content factors (99+%) were obtained under the same conditions.

No data are given for the Heavy Oil Skimmer since the device operated poorly without treatment of the oil with Elastol.

3.3.2 Effects of Waxy Oil

Because of the unusually warm temperatures prior to and during the tests, the water temperature in the basin never fell below the pour point (10°C) of the waxy Terra Nova C-09 crude oil, therefore a full evaluation of each skimmer's capabilities to deal with spills of waxy oils was not possible. Despite this setback, it was possible to draw some conclusions about mechanical recovery of spills of waxy crude oils on the Grand Banks.

The temperatures of the basin during the tests of the Framo ACW-400, GT-185 and Walosep W-2 (12-15°C) did approximate summer water temperatures on the Grand Banks (11.6°C in August - S.L. Ross 1984); the gelled surface oil's behaviour at the start of each test gave an indication of the ability of each skimmer to deal with and process gelled oil forms.

Comparison of the results with the Framo ACW-400 skimming IPL Sweet crude and Terra Nova C-09 crude showed that the recovery rate for the waxy oil (even at 3°C above its pour point) was 30-40% less than for the conventional crude (30 vs. 40 m^3/hr at 10 rpm and 33 vs. 53 m^3/hr at 15 rpm). Water entrainment rates while skimming waxy oil were three times those while skimming conventional crudes (3 m^3/hr vs. 1 m^3/hr), resulting in lower oil content factors (88 to 93% vs. 88 to 97%).

Comparison of the test results with the GT-185 skimming Terra Nova C-09 (at 12°C) and IPL Sweet crude showed little difference in oil/emulsion recovery rates, although during the initial stages of the test with Terra Nova recovery rates were reduced 15% over those recorded later (although this could be attributed to different pump settings) and the oil content factor was 90% compared to 99+% later.

Visual observations of the early action of gelled oil on the surface of the test area indicate that, had the Terra Nova C-09 crude oil been colder, the GT-185 would have had difficulty recovering the semi-solid chunks of oil.

Comparison of the data obtained with the Walosep W–2 operating in Terra Nova C–09 crude oil at 15°C and in the IPL Sweet crude shows no significant difference in oil/emulsion recovery rate (about 15 m^3/hr) or oil/emulsion content factor (98+%).

It is worthy of note that this skimmer drew in the chunks of gelled surface waxy oil at the start of the Terra Nova test and also drew in discrete chunks of heavily emulsified Bunker C at the end of that test. The chunks of Bunker C were recovered at a rate of 2 m^3/hr with an oil content factor of 10% in 0.68 m waves. This may represent the upper limit of this device to collect waxy oils at temperatures well below their pour point.

In general, the semi–solid nature of gelled, waxy Terra Nova C–09 crude initially on the surface of the test slick impaired flow of that oil into all of the skimmers; the low–adhesive nature of the waxy oil reduced its recovery rate on the oleophilic discs of the Framo ACW–400 skimmer. All three skimmers successfully tested could be applied to recover spills of waxy crudes in summer water temperatures on the Grand Banks; of the three the Walosep W–2 and the GT–185 are better suited to this task than the Framo ACW–400; primarily because of their superior wave response, lower water entrainment rates and gentler pump action. The Walosep W–2 may be best suited in the recovery of gelled oil forms because of the action of its rotor in drawing in semi–solid chunks of oil.

3.3.3 Effect of Elastol Treatment

The most dramatic effect of Elastol treatment of a test slick on a skimmers performance was for the tests with the Heavy Oil Skimmer. Recovery rates increased from 0 to 12 m^3/hr in IPL Sweet crude, from 0 to 5 m^3/hr in Bunker C and from 1 to 15 m^3/hr in Terra Nova C–09 crude oil with Elastol addition.

Elastol treatment improved the performance of the Walosep W–2 in IPL Sweet crude initially by about 40% (16 to 24 m^3/hr) but the increased load on the pump necessitated reducing its rate to 16 m^3/hr. Elastol treatment of Terra Nova C–09 crude is credited with enhancing the Walosep W–2's recovery rate by about 15% (14 to 16 m^3/hr).

The addition of Elastol to Terra Nova C–09 crude during the test of the Framo ACW–400 had no measurable effect on recovery rates and increased water entrainment rates. Elastol treatment of the IPL Sweet and Terra Nova C–09 crudes during the tests of the GT–185 skimmer reduced oil/emulsion recovery rates by 25–35% and increased water entrainment rates.

It is worthy of note that, when cleaning up the oil outside the test area, Elastol treatment of the thin (1 mm) slicks of oil visually enhanced the recovery rate of the MI–30 skimmers and allowed oil to be drawn to the skimmers from a considerable distance.

The application of Elastol to the test slicks proved to have negative consequences on the subsequent cleanup of equipment and storage tanks. The Elastol–treated oils and emulsions proved extremely adhesive and difficult to remove from skimmers requiring the use of large amounts of time and high pressure hot water and steam, whereas untreated oil or emulsion could be washed off relatively easily with low pressure cold water. In fact, it proved easier to clean Bunker C off equipment than Elastol–treated oil. Hoses through which Elastol–treated oil had been pumped proved extremely difficult to clean, requiring repeated soaking in diesel fuel followed by flushing with high pressure hot water and steam.

Perhaps the most difficult problem was pumping of Elastol treated oil from the holding tanks after the oil had sat for several days. One 23 m^3 (5000 gal) tank that contained a mixture of primarily untreated crude oil emulsion and the Bunker C took about one hour to pump out with a Spate 3–B pump; the other 23 m^3 holding tank containing primarily Elastolized (800–1000 ppm) crude oil and emulsion was pumped for 3 hours with a Spate 3–B and finally for an additional 2 hours with a high capacity gear pump before it was emptied. The high back pressures developed by Elastolized oil when pumping after the oil has sat for some time is illustrated by the fact that on two ocassions, the clamps on the discharge hose of a Spate 3–B failed while pumping Elastol–treated oil, and the fact that Elastol–treated oil caused the pump of a MI–30 skimmer to seize.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

- The Framo ACW–400 skimmer recovered oils and their emulsions with viscosities in the 10–300 cSt range at rates of 30 – 50 m^3/hr; increasing disc speed and lowering the weir both increased recovery rate in this range. Recovery rates decreased dramatically as the viscosity of the oil or emulsion increased above 1000 cSt, to 5 – 10 m^3/hr at 10,000 cSt. Oil/emulsion content factors in calm conditions ranged from 75–90% with crude oils and emulsions and 75 – 88% for Bunker C. Increasing disc speed and lowering the weir both reduced the oil/emulsion content factor. Although the unit operated reliably throughout the trial and effectively in calm water, the device's propensity to strongly emulsify recovered oil and entrained water in its centrifugal pump and its pitching action in waves, detract from its overall performance as an offshore skimmer.

- The GT–185 recovered oil and emulsion at a steady 25 – 30 m^3/hr, regardless of viscosity in the range 10 – 10,000 cSt or wave action. Oil/emulsion recovery rates were in the 5 m^3/hr range with Bunker C with a viscosity of some 90,000 cSt. Oil/emulsion content factors were consistently 90+% for crude oils and emulsions in both calm and wave conditions. Skimming of Bunker C gave oil content factors of 75 – 83% in calm conditions and 8 – 50% in waves. In general the skimmer operated well and reliably during the tests and followed waves well. Removal of the Light Oil Adapter, even with emulsion viscosities as high as 90,000 cSt, detracted from the skimmers performance.

- The Walosep W–2 recovered a steady 14 – 16 m^3/hr of oil and emulsion in the viscosity range 10 – 200 cSt. With very viscous (>100,000 cSt) Bunker C emulsion the recovery rate fell to 2 – 5 m^3/hr. Oil/emulsion content factors were consistently in the 98+% range with crude oils and emulsions, falling to 17 – 47% with the viscous Bunker C emulsion. The device operated reliably, even though underpowered, throughout the tests and followed waves well.

- The Heavy Oil Skimmer operated poorly in all tests, proving unable to recover oil without the addition of Elastol.

- Despite the fact that temperatures during the tests were not low enough to cause the waxy oil to gel completely, the tests showed that the GT–185, Walosep W–2 and Framo ACW–400 should be able to recover slicks of relatively fresh waxy oils and their emulsions at peak summer water temperatures on the Grand Banks (12°C). The test results showed that oil/emulsion recovery rates, under these conditions, would be 30 – 40% less than for a conventional crude with the Framo ACW–400 and about the same, as for a conventional crude with the GT–185 and Walosep W–2 skimmers. Oil/emulsion content factors were reduced (i.e., more water was entrained) for the Framo ACW–400 and GT–185 skimmers when skimming waxy oil compared to conventional oil; oil/emulsion content factors for the Walosep W–2 remained unchanged. Based on visual observations of the skimmers operating early on in the waxy oil tests, the Walosep W–2 may be the best one for recovering gelled oil pieces at colder water temperatures on the Grand Banks.

- The addition of Elastol to test oils and emulsions improved the oil/emulsion recovery rate of the Walosep W–2 by 15 – 40% (the former being the likely sustainable improvement), had no effect on the recovery rate but increased the water entrainment of the Framo ACW–400 and reduced the recovery rate of the GT–185 by 25 – 35% and increased its water entrainment rate. The addition of Elastol had several negative effects on subsequent downstream operations, including difficulty pumping and the level of effort required to clean Elastol–treated oil off equipment.

4.2 Recommendations

- Consideration should be given to testing the floatability and stability of the Framo ACW–400 skimmer head vis a vis modifying it to operate as a free–floating skimmer.

- The Light Oil Adapter for the GT-185 should be left in place during skimming operations, even with oil viscosities up to 100,000 cSt.

- Consideration should be given to improving the weir adjustment lever on the GT-185 power-pack to allow finer control of the weir immersion.

- Consideration should be given to modifying the Heavy Oil Skimmer to take advantage of its abilities to draw in Bunker C when operating in the downward rotation mode. The scraper blades should be spring-mounted for a smoother action.

- Further testing of the Walosep W-2 and GT-185 skimmers with completely gelled waxy oil pieces is recommended. A suitable power-pack for the Walosep W-2 should be utilized.

5.0 REFERENCES

Canpolar Consultants Ltd. 1986. Design, fabrication and testing of a heavy oil skimmer. Report to Canadian Coast Guard. Ottawa.

Gauthier, E. 1986. Transtech container and Detroil pump evaluation. Canadian Coast Guard. Ottawa.

Guenette, C. 1988. Full–scale evaluation of a steam siphon for breaking water–in–oil emulsions. Report to the University of Ottawa. Ottawa.

S.L. Ross Environmental Research Limited. 1984. Hibernia oil spills and their control. Report to Mobil Oil Canada Limited, St. John's, Newfoundland.

S.L. Ross Environmental Research Limited. 1985a. Spill–related properties of Terra Nova crude oils. Prepared for Petro–Canada Resources.

S.L. Ross Environmental Research Limited. 1985b. Adherence properties of aged crude oil from the Hibernia field. Mobil Oil Canada. St. John's.

S.L. Ross Environmental Research Limited. 1987. Offshore testing of booms and skimmers. Environment Canada. Ottawa.

S.L. Ross Environmental Research Limited and Hatfield Consultants Limited. 1986. Countermeasures for dealing with spills of viscous, waxy crude oil. Environmental Studies Revolving Funds report 058. Ottawa.

S.L. Ross Environmental Research Limited and D. Mackay Environmental Research Limited. 1987. The behaviour and fate of waxy crude oil spills. Environmental Studies Revolving Fund report 084. Ottawa.

S.L. Ross Environmental Research Limited. 1988. A study of equipment and techniques to dispose of oily materials from spill cleanups. Report to Canadian Coast Guard. Ottawa.

Zagorski, W. and D. Mackay. 1982. Water in oil emulsions: a stability hypothesis. Proceedings of the 5th Annual Arctic Marine Oilspill Program Technical Seminar. Environment Canada, Ottawa.

APPENDIX I

SKIMMER SPECIFICATIONS

FRANK MOHN FUSA A/S
P.O. BOX 10
N-5670 FUSA - NORWAY

FRAMO OIL RECOVERY SYSTEM
TYPE ACW-400

Reference:
Ref.: MP-1168
Page 1
HEB:BKJ

SYSTEM DESCRIPTION.

FRAMO ACW-400 is designed for instant installation on vessels capable of manoeuvring along oil containment booms and operate the skimmerhead in the accumulated oil layer ahead of the boom.

The equipment as per drawing 305-696-1 comprises the skimmerhead, extension arm and the powerpack. The skimmerhead is launched over the boom and stabilized by the extension arm. The arm is dynamic hydraulically balanced and allows the skimmerhead to follow the main sea movements automatically. The oil transfer line and the hydraulic transmissions are integrated in the arm construction eliminating hose handling problems.

The skimmerhead is connected to the arm by a flexible joint and a floating body gives the required buoyancy. The oil is recovered from the sea surface by a combination of adhesion and weir skimming principles, particularly advantageous for handling of viscous oil and emulsions and improving the overall performance. Four transport drums with vertical discs accumulate the oil ahead of an adjustable weir (pumpwell) forcing the water level down and create a heavy layer that is skimmed into the pumpwell with minimum water content. The weir position can be steplessly adjusted depending upon the actual oil viscosity and layer thickness.

The dieselhydraulic powerpack is mounted on brackets on the rear of the loader body and rotates with this. All hydraulic connections to the powerpack are fitted with valved snap-on couplings. The complete powerpack can thus easily be disconnected and be utilized independently for operation of a portable submersible pump for transfer, emergency offloading, firefighting etc.

All controls for the extension arm and the skimmerhead are arranged in an operator cabin on the left of the loader body.

The ACW-400 is assembled as a selfcontained unit on a steel base and is after installation ready for operation independent of other handling equipment. Before operation the base should be secured by bolting or welding.

As optional equipment the base can be fitted with hydraulically lowered wheels for slow transport.

A portable submersible transfer pump is included in the system. The pump is hydraulically powered and is connected to the dieselhydraulic aggregate by flexible transmission hoses. The pump is lowered into tanks through 12" hatches and is specially designed for transfer of viscous oils over considerably distances. Due to high discharge head the pump is suitable for firefighting and might also be used for emergency offloading of chemicals, solvents, etc.

As optional equipment, the extension arm can be fitted with a special gravel pump with cutter head for recovery of extremely viscous materials, such as oilcontaminated sand, mud, reed, etc.

RECOVERY PERFORMANCE, ACW-400.

Operational conditions	Capacity/head.	Water content beyond emulsion.
A) Viscosity 100 c.Stoke		
Oil layer 20 cm.	400 m3/h. - 35 mwc.	Max. 20%
Oil layer 2,5 cm.	60 m3/h. - 45 mwc.	Max. 10%
B) Viscosity 500 c.Stoke		
Oil layer 20 cm.	250 m3/h. - 40 mwc.	Max. 15%
Oil layer 2,5 cm.	100 m3/h. - 45 mwc.	Max. 10%.
C) Viscosity 1500 c.Stoke		
Oil layer 20 cm.	150 m3/h. - 35 mwc.	Max. 10%
Oil layer 2,5 cm.	100 m3/h. - 40 mwc.	Max. 15%

The above data are based upon laboratory tests and experiences from offshore oil recovery operation during the Ekofisk blow-out.

The FRAMO ACW-400 is designed for operation under sea-state 4-5, Beaufort scale, with significant wave of 2,5 m., frequency 5 sec.

Based upon the results achieved during the recovery operation at the Ekofisk field the system was approved by the Norwegian Authorities for the North Sea Contingency maintained by the field operators, NSOC-N.

TECHNICAL DATA, FRAMO ACW-400, DRWG.305-696-1.

A) THE SKIMMER HEAD, drwg. No. 305-700-1, is fitted with four transport drums with vertical discs mounted in a square configuration.

A total of 168 aluminium discs, Ø500 mm. are mounted on the drums, giving an extended surface area of abt. 60 m2. The drums are assembled on an aluminium fuselage with four pontoons and have a fixed draught with the lower part of the solid drum at the waterline as a wave damper. The discs are extended 150 mm. into the water. The drums are internally connected by angel pinions and are operated by 2 hydraulic radial piston motors of Danfoss manufacture, max. work. pressure 250 kp/cm2. The speed of the drums is steplessly adjusted from 0-20 rpm. For removal of debris the rotation of drums can be reversed.

Materials in fuselage and discs: Aluminium A57 (NS17210).

The pumpwell with the weir is connected by four hydraulically operated lifting cylinders of working pressure 150 kp/cm2. to the fuselage. The level of the weir is adjustable in relation to the waterline from -50 mm. to + 100 mm. In the lower position the pumpwell is open for free flow of the (50 mm.) surface layer. In the upper position the weir barrier close towards the guiding vanes and all oil will have to be transported by discs, and guiding vanes into the pumpwell.

The transfer pump type TK6 of centrifugal design is assembled in the pumpwell with the suction inlet flush in the bottom.

Material in housing:	Aluminium (silumin)
Material in impeller:	Stainless steel AISI 316.
Max. transfer performance:	400 m3/h. - 35 mwc.
Motor:	Hydromatik, axial piston.
Hydr. working pressure:	Max. 250 kp/cm2.

The skimmer head is fitted with a 30 degr. flexible joint for connection to the extension arm. Oil discharge line and hydraulic transmissions are arranged with flexible hoses and valved snap-on couplings. The maximum draught of the skimmer head is 750 mm.

B) THE EXTENSION ARM WITH LOADER BODY, OPERATOR CABIN AND BASE, is constructed for safe launching and positioning of the skimmer head under the environmental conditions as described under "Performance". The arm is fitted with two knee joints for adjustment of extension and parking. Maximum extension 10,5 m. All hydraulic transmissions and the oil transfer line are integrated in the arm construction, eliminating hose handling problems. The two main lifting cylinders of total 13.000 kp., are dynamic hydraulically balanced and compensates the weight on the skimmer head to 60 kp when in floating position.

The loader body will turn 360 degr. with maximum torque 3.300 kpm.

All control valves for operation of the arm and skimmer head are assembled on a panel in the operator cabin. The cabin is mounted on the loader body and turn with this.

Connections from the front end of the arm to the skimmer head is arranged with valved quick couplings.

Diesel fuel tank of volume 300 l. and stand-by hydraulic oil tank are mounted on the loader body.

C) THE DIESELHYDRAULIC POWERPACK, drwg. No. 305-509-1 is designed for continuous operation of arm and skimmer functions. Alternatively the powerpack can operate the portable pump (TK5) for transfer of collected oil from the recovery vessel to receptacles.

The powerpack is mounted on the loader body. All hydraulic transmission lines are arranged with valved quick couplings and the complete selfcontained powerpack can easily be disconnected and utilized separately for operation of the portable pump for emergency offloading, etc.

Diesel engine:	GM, 6 cyl. V53.
Engine rating:	175 HP at 2500 rpm.
Starting:	Hydraulic, spark proof.
Exhaust:	2 x silencer, spark arrestor.
Internal fuel tank:	45 l.
Hydraulic pump.	Voith trippel gear pump.
	Capacity (A) 205 l/min. - 250 kp/cm2.
	Capacity (B) 80 l/min. - 220 kp/cm2.
	Capacity (C) 20 l/min. - 250 kp/cm2.
Oil cooler:	Water cooling, built-on engine.
Hydr. oil tank:	90 l. volume.
Spare hydr. oil tank:	90 l. volume.

The powerpack is assembled as a compact unit on slide base with weather protection.

Dimensions:	L = 2000 mm., B = 1100 mm., H = 1550 mm.
Total weight:	Approx. 1400 kgs.

D) TRANSPORT WHEELS AND TOWHOOK, drwg. No. 305-291-1 mounted on the base of the oil recovery unit. The equipment is designed for slow transport only. The wheels are manually/hydraulically lowered.

E) TRANSPORT AND INSTALLATION.

The ACW-400 recovery unit is designed for transport and installation as one complete package ready to start. The total weight is approx. 7000 kgs. and required deck space is 2,7 m. by 7,4 m.
Max. height is 3,6 m. (Arm in parked position).

For permanent installation onboard vessels the base can be simplified and the recovery unit arranged to meet special space requirements.

The standard ACW-400 (dieselhydraulic operation) drwg. No. 305-151-1, can also be splitted up for transport by helicopter or airplane as shown below.

Item 1, comprising, main base, loader body, oil tanks and first part of arm.

Total weight (incl. oil): Approx. 3300 kgs.
Dimensions: L = 3,5 m., H = 2,65 m., B = 2,5 m.

Item 2, comprising, base, front and mid part of arm, skimmer head.

Total weight: Approx. 2300 kgs.
Dimensions: L = 5,0 m., H = 1,5 m., B = 2,5 m.

Item 3, comprising, dieselhydraulic powerpack.

Total weight (incl. oil): Approx. 1400 kgs.

The el. powerpack is fitted with separate radiator type oil cooler for max. 32 degr. C. ambient.

Hydraulic oil tank of volume 750 l/min. Normal filling 500 l.

NB: The el.powerpack and the operator cabin are placed on the main base, not on the loader body as for the diesel unit.

El. starter and 40 m. of supply cable is included.

G) THE PORTABLE SUBMERSIBLE TRANSFER PUMP TYPE TK5 is designed for discharge of the collected oil from the recovery vessel and for firefighting and emergency offloading.

The pump is designed for entering through Butterworth size tank openings (12") and can handle all petroleum products, sea water and most chemicals. The pump is complete with 18 m. of hydraulic transmissions hose of neoprene.

Capacity (A):	300 m3/h. - 20 mwc. (sp.g. 1,0).
Capacity (B):	200 m3/h. - 70 mwc. (sp.g. 1,0).
Capacity (C):	140 m3/h. - 90 mwc. (sp.g. 1,0).
Weight excl. hoses:	70 kgs.
Materials against cargo:	Stainless steel AISI 316.

The pump is complete with adaptor flange and flexible transmission for pressure/return hydraulic oil.

H) TRANSFER/DISCHARGE HOSE:

20 m. x 6" rubber oil hose complete with flanges or quick couplings.

I) HYDRAULIC TRANSMISSION HOSE:

18 m. x 1" highpressure hose complete with snap-on couplings.
18 m. x 2" return pressure hose complete with snap-on couplings.

J) SUBMERSIBLE HYDRAULICALLY DRIVEN DREDGE PUMP TYPE B3, for mounting on the extension arm.

The pump is designed for transport of products of extreme viscosity like oil contaminated sand/mud or reed with solids of maximum 100 mm. The impeller is of mixed flow type with cutter head.

Capacity, sand/water mix. 1:4:	Total 400 m3/h.
Material in housing and impeller:	Wear resistant mild steel.
Weight:	480 kgs.

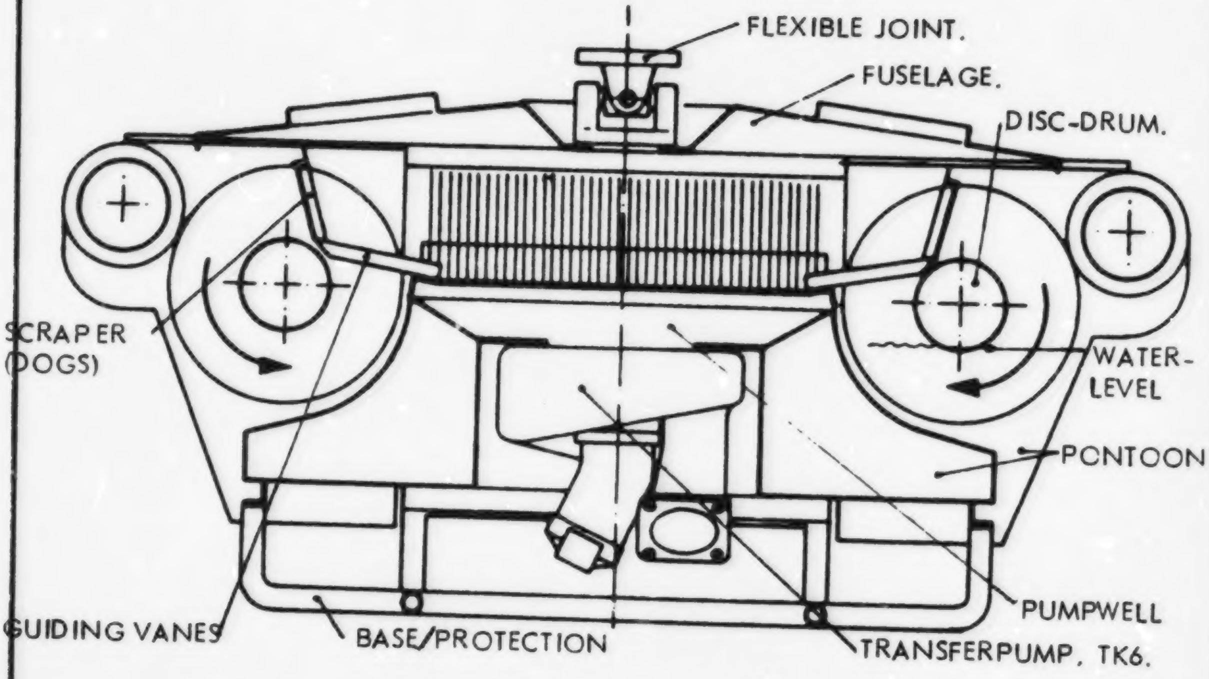
---ooo0ooo---

K) Recommended spares/tools for Oil Recovery System, diesel hydraulic version:

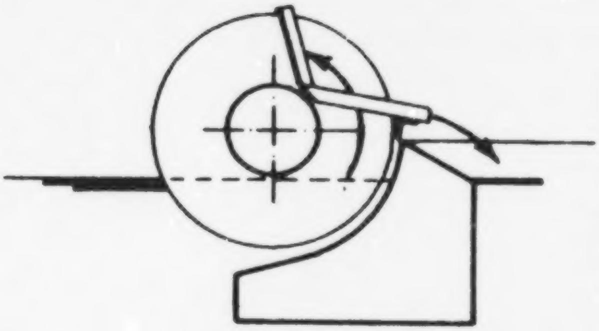
Qty.	Article.
1 set	Shaft bearings for hydr. motor, TK6 pump.
1 set	Shaft bearings for hydr. motor, skimmer head.
1 set	Shaft bearings for hydr. pump, powerpack.
1 set	Hydr. hoses between powerpack and skimmer head.
1 set	Scrapers for skimmer head.
4 off	Angel pinions, skimmer head.
1 off	Disc drum skimmer head.
2 off	Shaft bearings skimmer head.
6 off	Snap-on couplings for powerpack and hydr. hoses skimmer head.
1 set	Bearings for cylinders on extension arm and skimmer arm.
1 set	Tools comprising unbraco keys, combination spanner, sockets, pipe tongs, grease gun, screw driver, wrench and extractor for TK6 pump.
1 set	Assembly tools.
1 off	Ters.
1 set	Spares for diesel engine according to DnV (Det norske Veritas).
1 off	Universal joint for skimmer head.
1 off	Complete drum with scrapers.
1 off	Stainless steel impeller for TK6 pump.

---ooo0ooo---

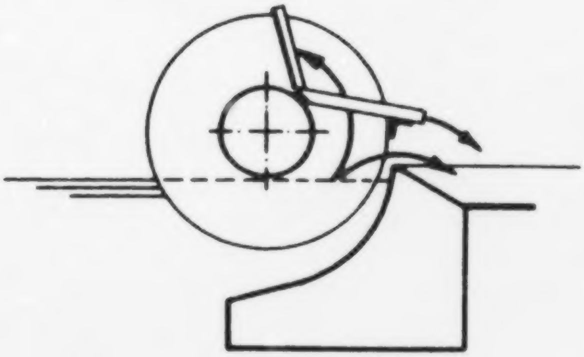
SKIMMER HEAD


FLEXIBLE JOINT.
FUSELAGE.
DISC-DRUM.
SCRAPER (DOGS)
WATER-LEVEL
PONTOON
PUMPWELL
GUIDING VANES
BASE/PROTECTION
TRANSFERPUMP, TK6.

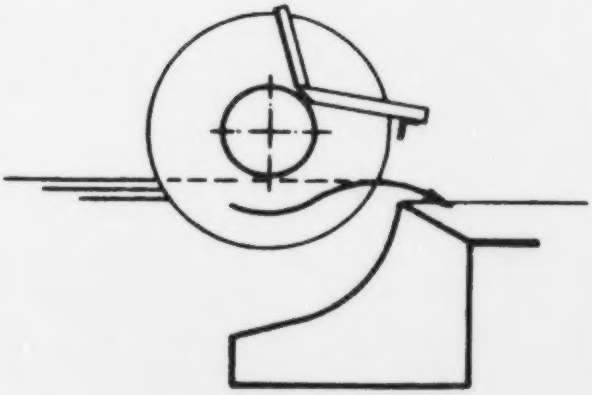
MAIN OPERATION PRINCIPLE.



PUMPWELL / WEIR IN UPPER POSITION. ALL OIL TO BE CARRIED OVER ADHESION-DISCS: MAX CAPACITY: 100m^3/h.



PUMPWELL/WEIR IN MIDDLE POSITION. SURPLUS OIL ACCUMULATED UNDER GUIDING VANES GRAVIATES OVER THE WEIR.



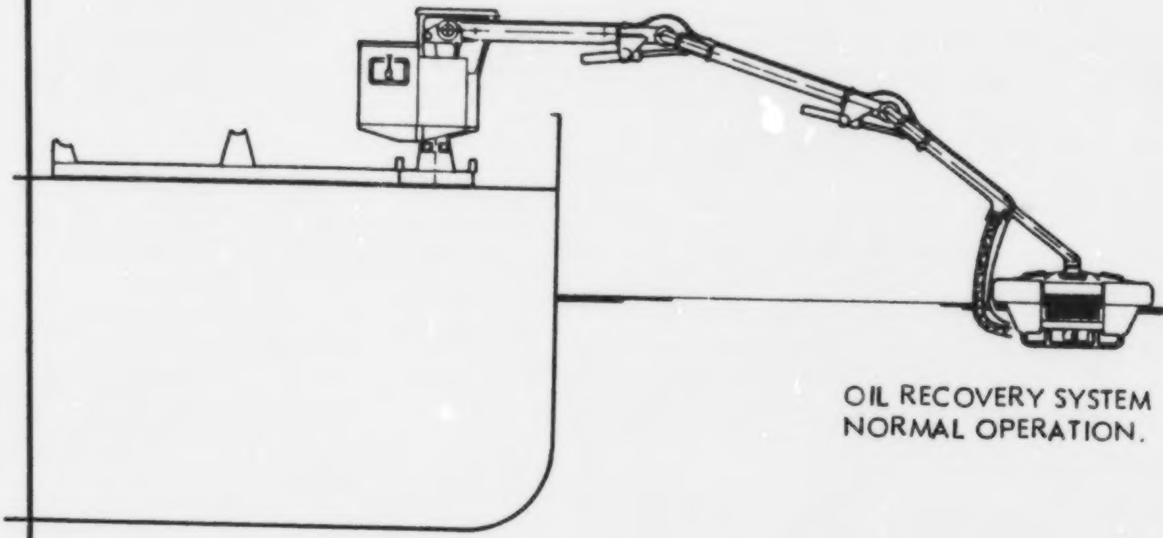
PUMPWELL/WEIR IN LOWER POSITION. THE OIL GRAVIATES INTO THE PUMP WELL AND DISC-DRUMS IMPROVES THE FLOW TO THE SKIMMER HEAD AND THE WEIR.

FRANK MOHN FUSA A/S
P.O. BOX 10
N-5670 FUSA - NORWAY

FRAMO OIL RECOVERY
AND EMERGENCY OFFLOADING
SYSTEM.

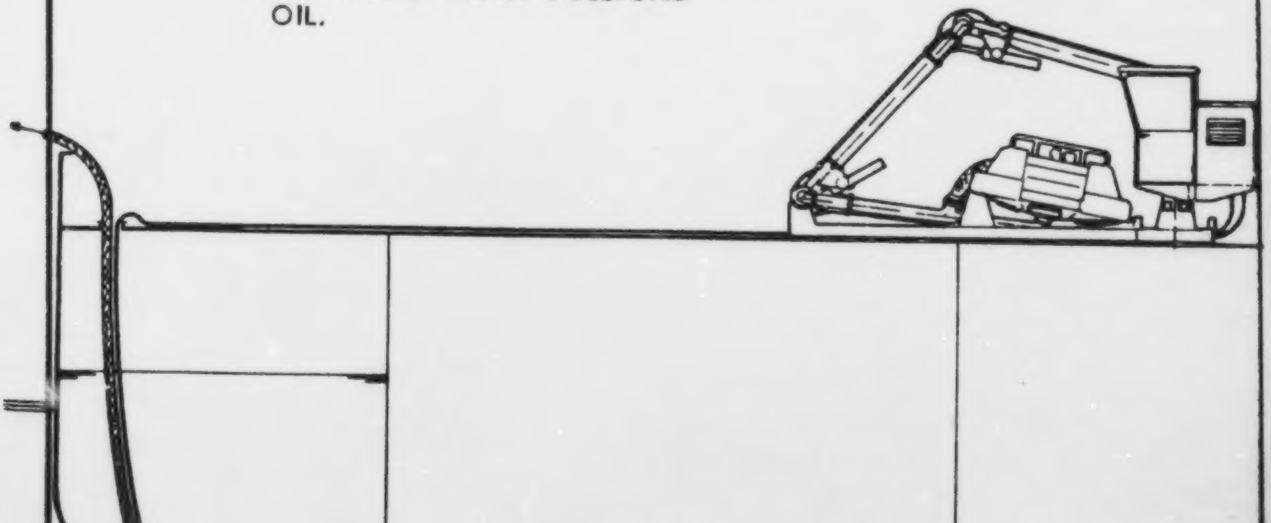
Reference:

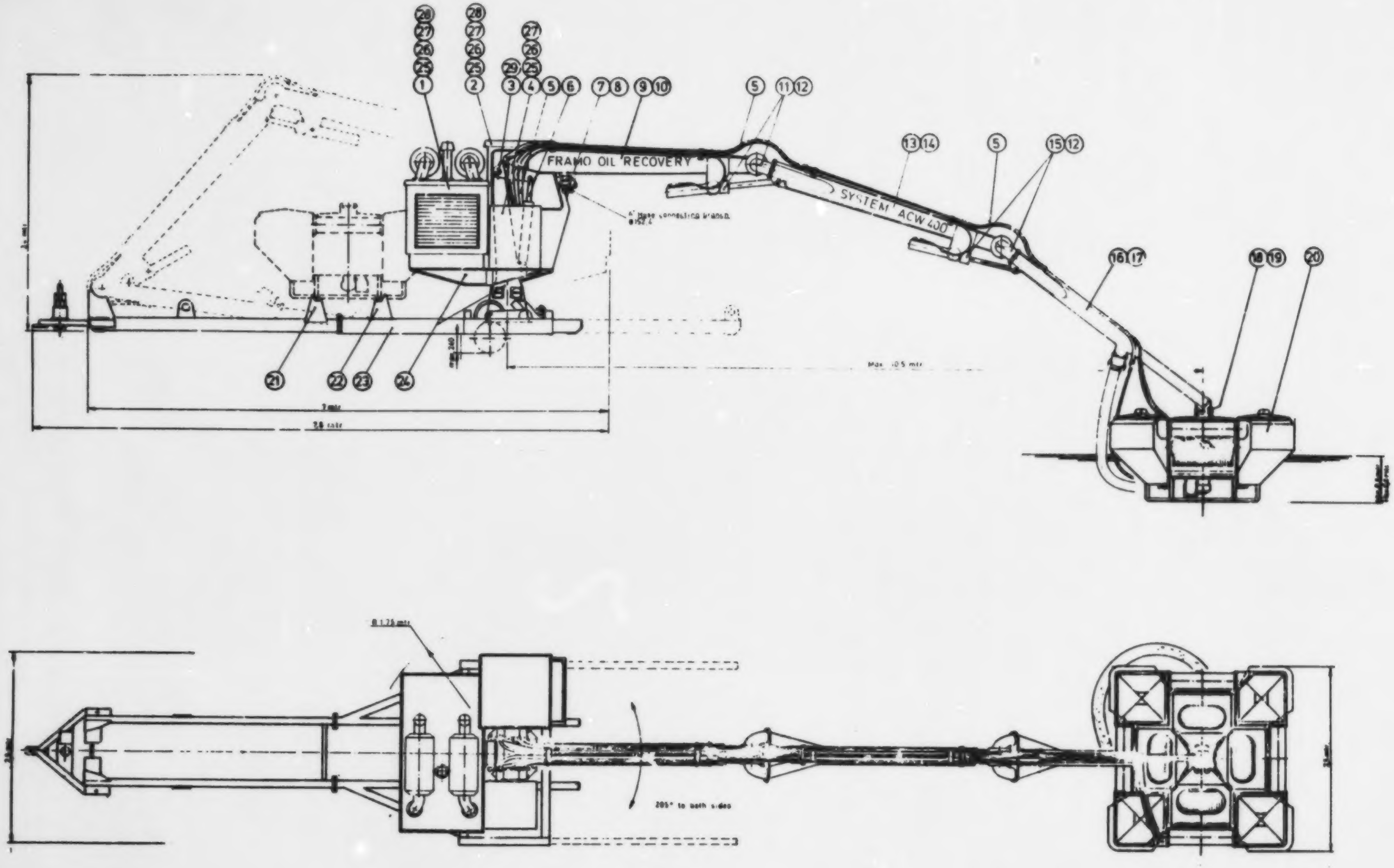
APPLICATION ACW 400.



OIL RECOVERY SYSTEM
NORMAL OPERATION.

ARM AND SKIMMERHEAD
IN PARKED POSITION.
PORTABLE TRANSFER PUMP
CONNECTED TO POWERPACK
FOR DISCHARGE OF COLLECTED
OIL.




1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
FRAMO OIL RECOVERY
SYSTEM ACW 400
4" Hose connecting branch Ø152.4
Max. 10.5 mtr
9 mtr
205° to both sides
Ø 1.75 mtr

Test control instruction 305-409-3
Control report form. 305-408-4
Item's list drg.no. 305-697-3

SYM	REVISION	DATE	FRANK MOHN A/S PUMP & GEAR BERGEN NORWAY		1:25		FRAMO OIL RECOVERY SYSTEM type ACW 400	305-696-1

MICROBOX

ITEM	QTY	ART NO	DESCRIPTION	REMARKS.
01	1		Diesel/hydr. aggr	
02	1		Cabin w/control valves	
03	1		Bolt	
04	1		Tank for fuel	
05	1		Hydr. hoses	
06	1		Lifting cylinders	
07	1	57786	Snap on coupling	
08	4	68544	Stud screw	
09	1		Crane tube no. 1	
10	1		Hydr. pipes/tubes no. 1	
11	1		Hydr. cylinder	
12	2		Ass. crane tubes	
13	1		Crane tube no. 2	
14	1		Hydr. pipes f tube no. 2	
15	1		Hydr. cylinder	
16	1		Crane tube no. 3	
17	1		Hydr. pipes for tube no. 3	
18	2		Bolt	
19	2		Lock pin	
20	1		Skimmer unit	
21	2		Skimmer base	
22	2		Skimmer base	
23	1		Base plate	
24	1		Crane column	
25	28		Hex. head screw	
26	28	04036	Hex. nut	
27	28	04200	Spring washer	
28	1		Vibration dampers	
29	2	56549	Hex. head screw	

REMARKS.

Ind.	REVISJON	DATE

This drawing is the property of FRANK MOHN A/S. It is not to be traced, copied or published without their written consent, nor to be misused in any way.

FRAMO

FRANK MOHN A/S
PUMP & GEAR WORKS
BERGEN - NORWAY

	SIGN.	DATE
Constr.	HB	10/9-79
Traced		
Checked		

ITEM'S LIST TO
DRG. NO.
305-696-1

Replaces
305-697-3

Replaced by

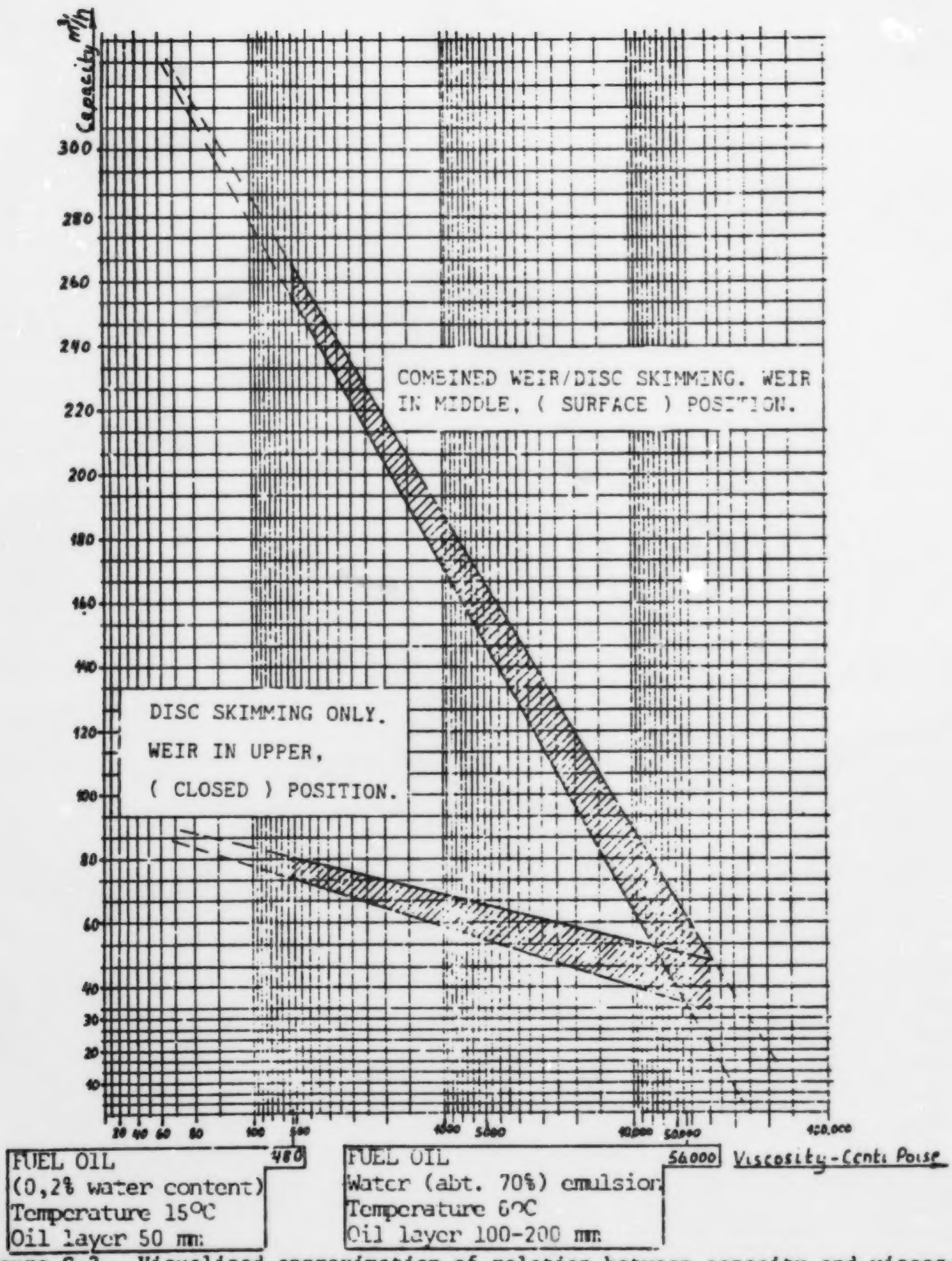


Figure C-3. Visualized approximation of relation between capacity and viscosity for Framo ACW-400 oil recovery system (based upon results from workshop testing with supervision and monitoring by DNV, Bergen).

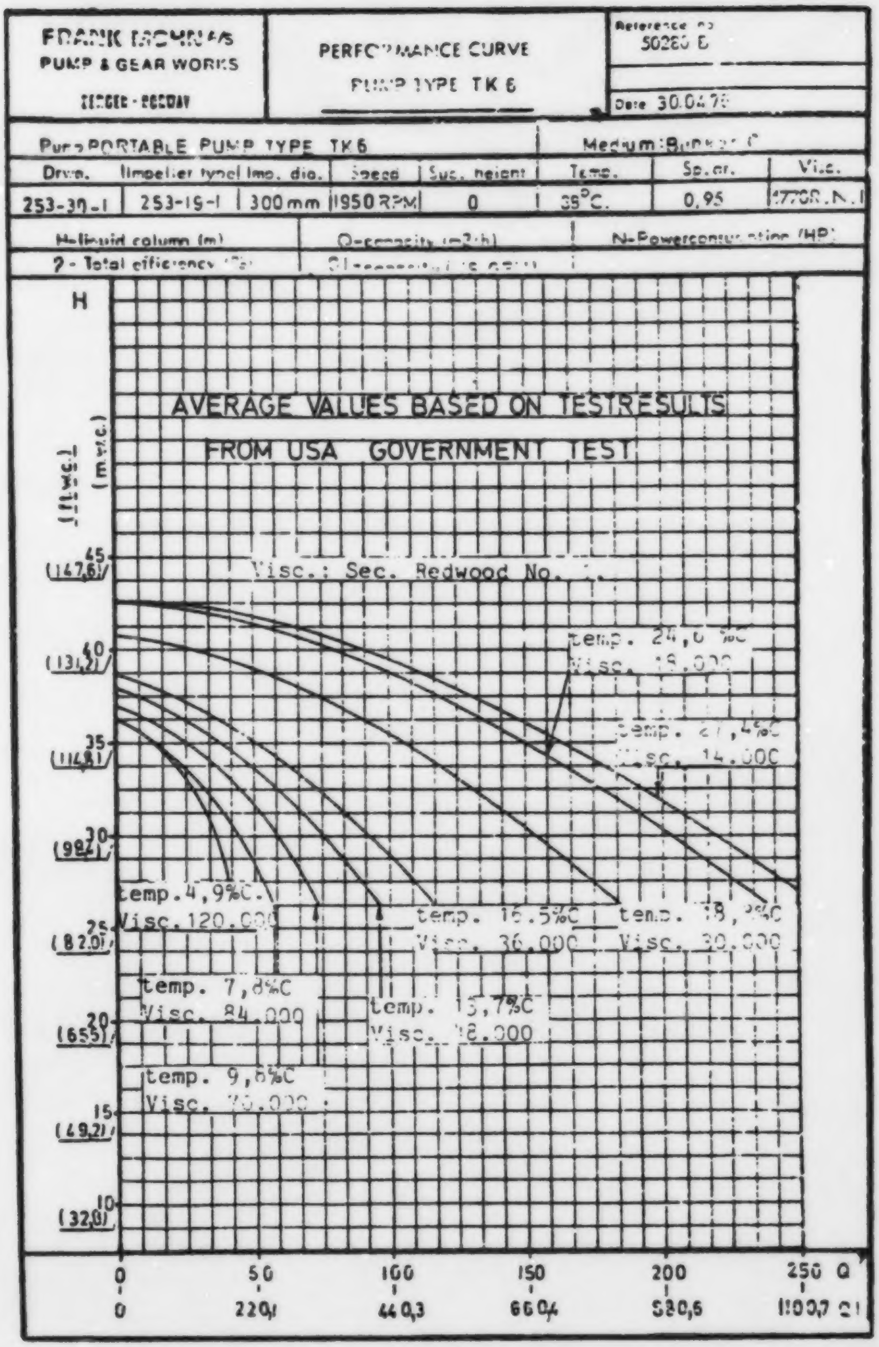


Figure C-4. Upper limits for Framo ACW-402 oil pickup rates.

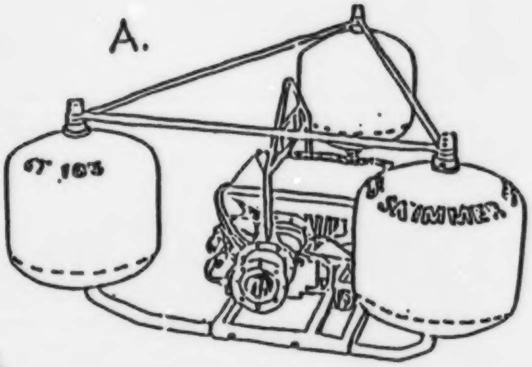
1. BRIEF DESCRIPTION OF THE GT-185 OIL RECOVERY SYSTEM

The standard system consists of three main components:

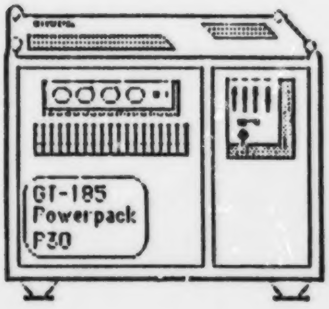
A) Skimmer (pump and floating system) with light oil adapter
B) Diesel/hydraulic Powerpack P-20
C) Hydraulic and discharge hoses

Optional extras: Hosereel, Remote Control Unit, High Pressure Cleaning Unit, GT-185 Crane.
Various types and sizes of diesel or electric driven powerpacks.

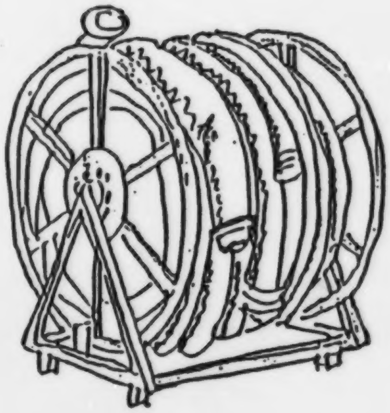
A.

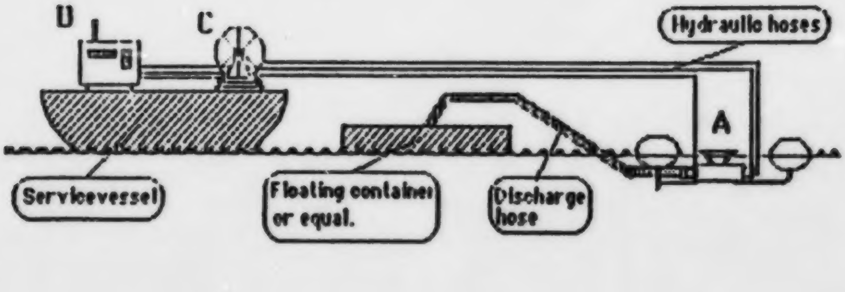

GT 185
SKIMMER

B.

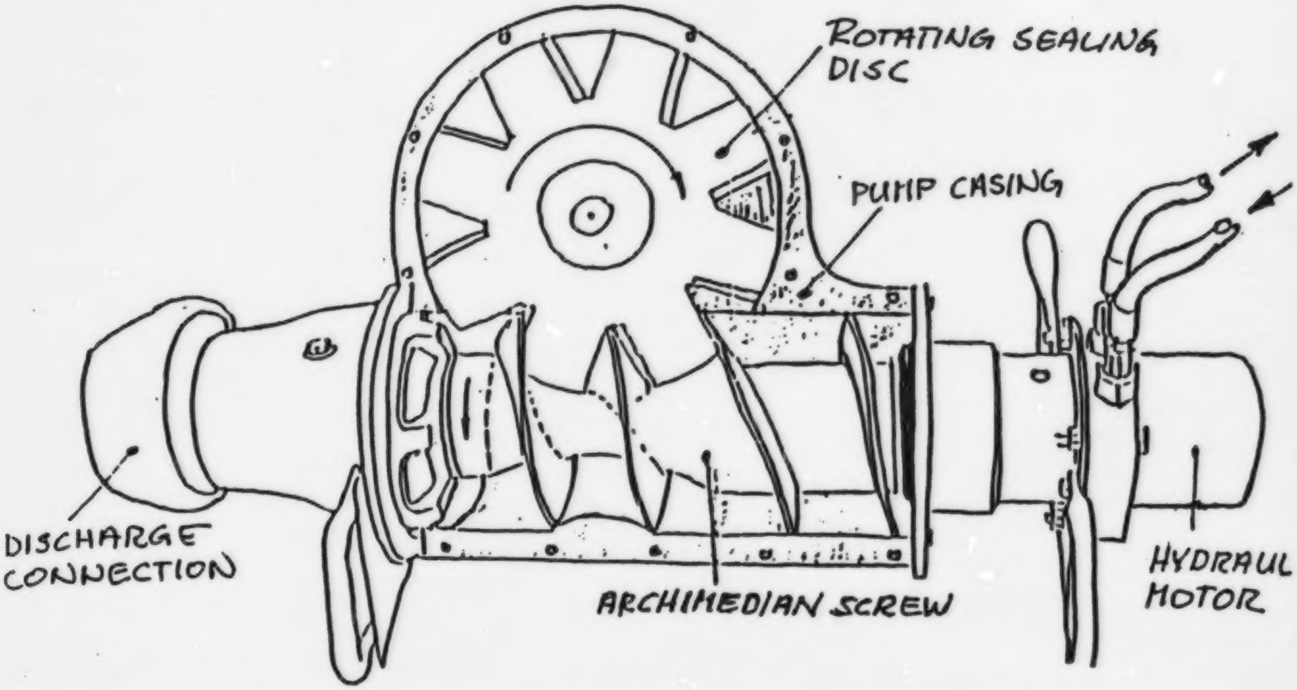

GT-185
Powerpack
P30

C.




B
C
Hydraulic hoses
A
Servicevessel
Floating container or equal.
Discharge hose

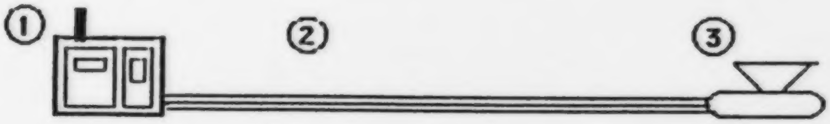
The pump design of the **GT-series of Skimmer/Pumps** are all based on the Archimedian principle. The pump consists of a modified Archimedian screw with a rotating slotted sealing disc placed in a split pump casing with a radial suction and axial pointing discharge.

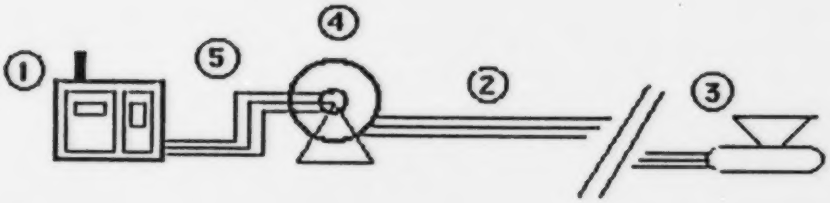


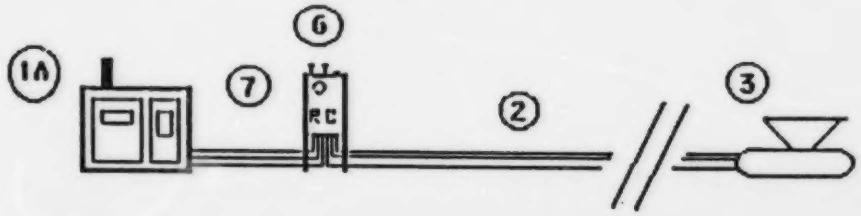
The prime mover is a hydraulic motor connected to the screw via a rigid coupling. The motor is connected via hydraulic hoses to a suitable hydraulic power source. (Diesel or electric - hydraulic powerpack)
The suction end of the pump is fitted with a hopper. When the pump is used as a skimmer i.e., with the hopper in the floating oil layer to be removed, the depth-control of the hopper in the GT-185 and the GT-260 models is carried out by a spring loaded single acting hyd. cylinder manœuvered from the powerpack. With the GT-185 ECONOMY the required depth is obtained by manual setting of the pontoons in the floating system.
The "up & Down" movement is always parallel with the oil/water surface ensuring max. recovery efficiency. Since the control of the skimming depth is independant of the types of pontoons beeing used customized systems for specific needs can easily be fitted.
The standard three pontoon system is well proven and works under all sea conditions.
By undoing three bolts the pump can be removed from the floating system and used for dry or wet transfer applications
This quality together with the complete viscosity coverage makes the **GT-Series of Skimmer/Pumps** unique and extremly versatile.

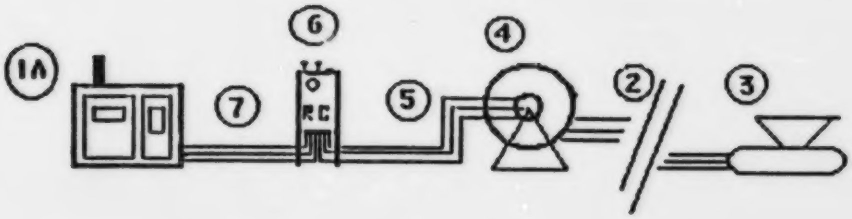
CONNECTING DIAGRAM FOR GT-185 COMPONENTS

① POWERPACK
(1A) P-PACK OR OTHER HYD. SOURCE
② HYD.MAINHOSES
③ SKIMMER
④ HOSEREEL
⑤ 8M. HOSES
⑥ REMOTE CONTROL
⑦ X M. HOSES



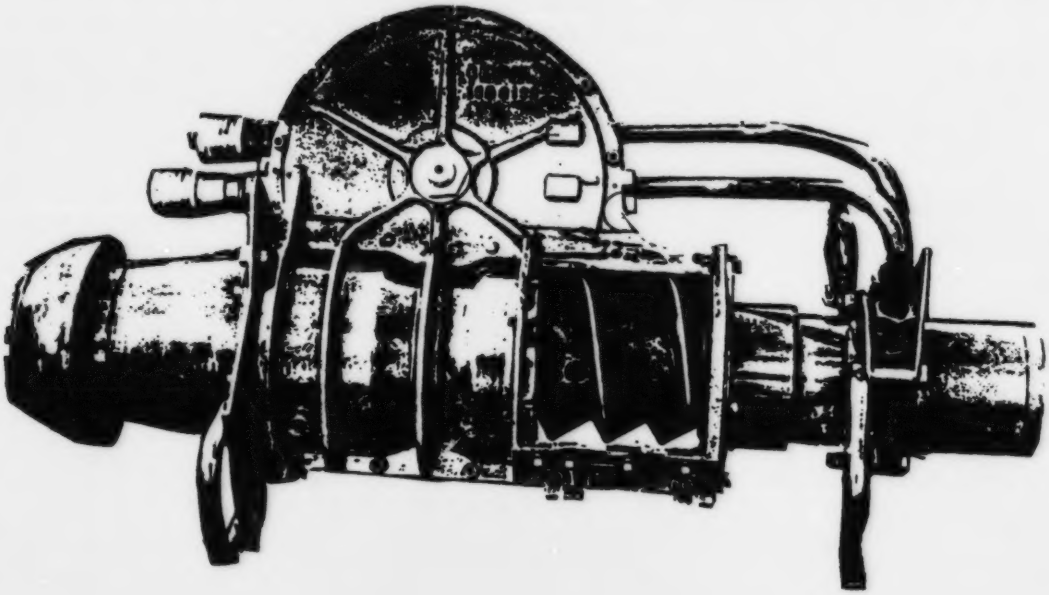





(1A)
⑦
⑥
RC
⑤
④
②
③

GT-185 HEAVY DUTY TRANSFER PUMP

The GT-185 Heavy Duty Transfer Pump is a very powerful pump for submerged as well as dry applications. It is especially designed to handle extremely viscous oils and can be used far beyond the range of any conventional designed pump. Some of the applications where the GT-185 is used includes: Transfer of recovered oil after oil spills, pumping out crude or fuel oil from disabled ships, emptying of oil ponds, sludge removal from oil storage tanks, circulation of heavy oil to prevent settling, pumping of melass, jelly fish or scrapfish.



GT-185 fitted with 6" quick coupling connection as delivered to an oil refinery in Egypt

The **GT-185 Heavy Duty Transfer Pump** can be delivered with a stainless steel hopper, 400 or 600 rpm hydraulic motor, and a wide choice of discharge connections from 2" to 6".

GT-185 Skimmer / Pump Specification

Swedish Patent No: 81-01863-2
Lloyd's Register of Shipping Type approval No: 86/0015

Principle:	Archimedian screw with rotating sealing disc.
Pump Casing:	Split casing design. Material: Nodular iron, Nickel lined
Screw:	Computer designed with double spiral in connecting area between screw and rotating disc. Material: Cast stainless steel.
Shaft Sleeve:	Renewable. Material: Stainless steel, hard cromed. Only in pumps fitted with forward sleeve bearing.
Rotating Disc:	One piece open slot design. Material: Special composite glass and carbon fibre reinforced epoxy. Nitril rubber sealing.
Rotating Disc Scraper:	Stainless steel plate.
Screw Bearings:	Driving end: double SKF ball bearing, grease lubricated. Discharge end: Ball bearing or sleeve bearing.
Debris Cutting Knives:	Two in the suction inlet. Three at the discharge end. all renewable. Material: stainless steel.
Suction Hopper:	Welded in stainless steel.
Discharge:	4" quick coupling or flange, other sizes on request.
Lifting Yoke:	Balanced. Material: steel pipe.
Carrying and Protection Frame:	Encircling the pump for ease of transportation.
Driver:	Hydraulic motor Type: rotary Max. cont. pressure: 140 bar Intermittent: 210 bar Displacement: 138 cm^3 Flow at 600 rpm. 83 l/min.

Shaft Coupling:	Fixed type. Material: stainless steel.
Hydraulic Couplings:	Quick connecting type.
Floating System:	The pump is fitted with three bolts to a welded aluminum frame. A hydraulic cylinder activates a link system allowing the pump to move up and down. The frame is fitted with three floats for adequate buoyancy but can be fitted with customized floats. Up and down movement of the hopper is independant of the type of floats and parallel with the water/oil surface. Float displacement: 85 lit. each float.
Painting:	All pump and frame parts except stainless steel and anodized parts are LEVASINT treated (powder/heating methode) for long term protection and easy cleaning.
Skimmer/Pump Capacity:	Displacement 1.25 lit./rev. giving 45 m^3/hr. at 600 rpm. Capacity may vary depending on oil viscosity and pressure drop in the discharge hose.
Viscosity Range:	0 -> 1 mill. cSt.
Max. T.D.H. (pump pressure)	16 bar (heavy oil)
Light Oil Adapter:	To be used as long as the oil is fluid (ca. 15000 cSt.) The adapter is of "snap-on, snap-off" type. Materials: stainless steel. Bellow of oil resistant rubber.
Weight:	Pump only 82 kg. Complete skimmer150 kg. Light oil adapter 8.5 kg.
Dimensions:	Please see separate drawing.

This specification may change without notice

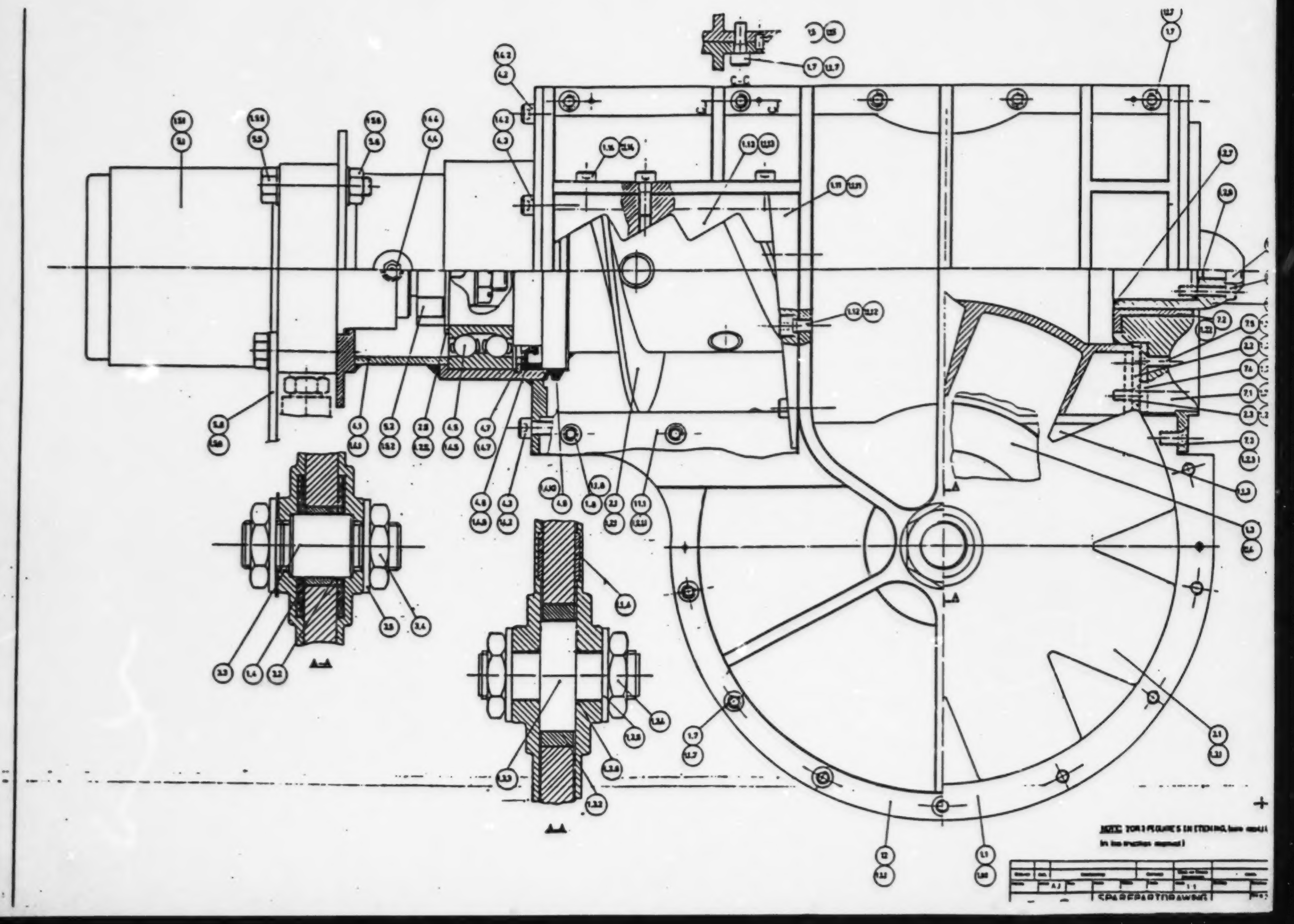
GT-185 and GT-185 ECONOMY

Spareparts and tools included with each delivery

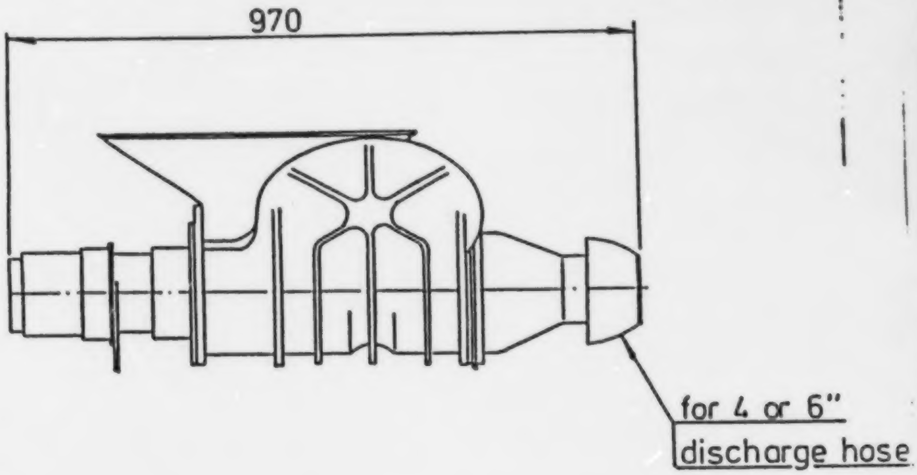
Item number	No	Item
Pump		
1.1.3	2	Wear plate
1.1.4	2	Wear ring
1.1.6	1	Sealing compound
1.1.7	4	Screw MC 8x25
1.3.1	1	Rotating sealing disc
1.3.7	1	Grease nipple
1.4.8	1	Sealing ring
1.4.10	1	V- ring 130 S
1.5.9	1	O- ring 74 x 4
1.9.2	3	Screw MC 6 S 8 x 35
1.10.4/+A	2 set	Quick coupling Tema 7511/7521
1.10.5/+A	2set	Protective cap 7515/7525
Floating system		
2.2.9	2	Splitcotter SR 5x50
2.2.10	4	Splitcotter SR SP 3x25
2.2.11	4	Washer SR BrB 17x30
2.2.12	4	Nyliner bushing
2.3.6/+A	1 set	Quick coupling Tema 3811/3821
2.3.7/+A	1set	Protecting cap Tema 3815/3825
2.5.10	3	Locking ring SR

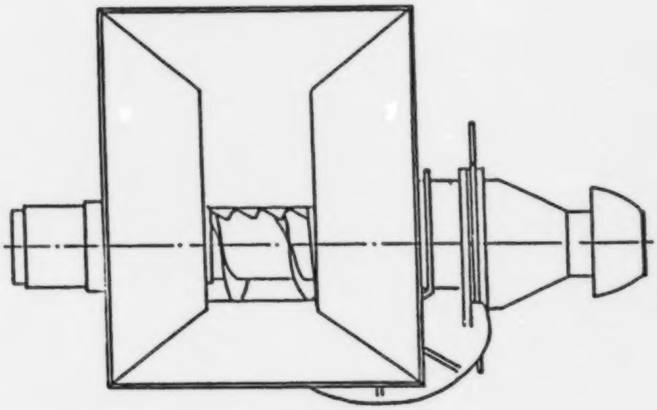
Tool Kit

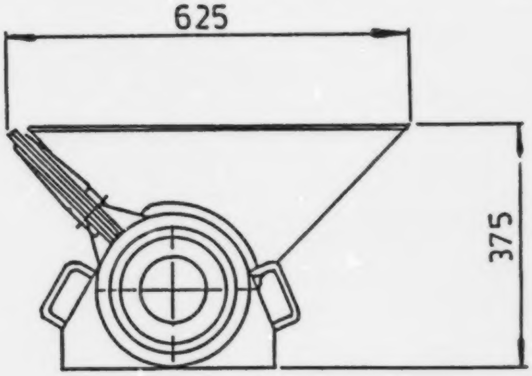
1	Wooden toolbox
1	Pinch bar
1	Hexagon chisel
1	Hexagon wrench 4 mm
1	Hexagon wrench 5 mm
1	Hexagon wrench 6 mm
1	Hexagon wrench 8 mm
1	Open spanner 46 mm
1	Open spanner 24 mm
1	Open spanner 17 mm
1	Open spanner 13 mm
1	Grease gun + extension
1	Ratchet wrench 1/4"
1	Extension rod 120 mm
1	Hexagon wrench socket


C-C
A-A
A-A
AJ
1:1
SPAREPARTDRAWING

Nr	Ant.	Ändring och/eller medd.-nr	Datum	Inf.	Godk.	8.


970
for 4 or 6" discharge hose





This spec. can be changed without notice.

Det.-nr	Ant.	Benämning	Material	Mod.-nr Ämne Dimension	Anm.

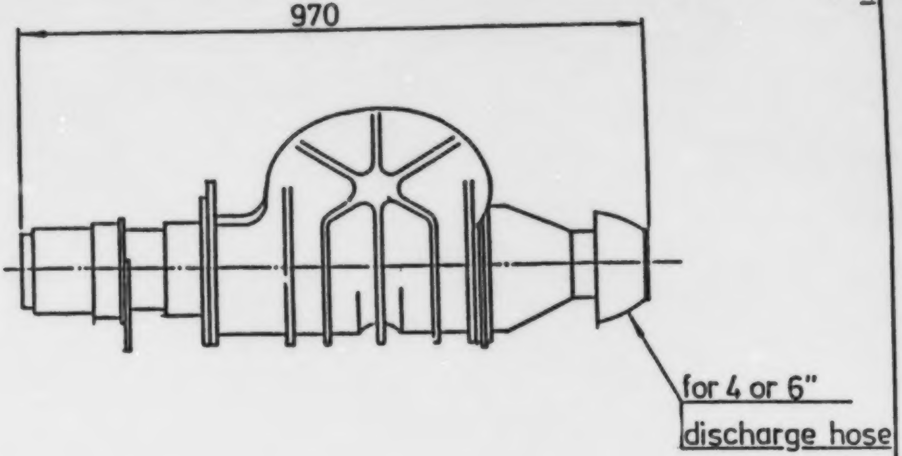
Konstr.	Ritad	Kop.	Kontr.	Stand.	Godk.	Skala	Ersätter	Ersatt av

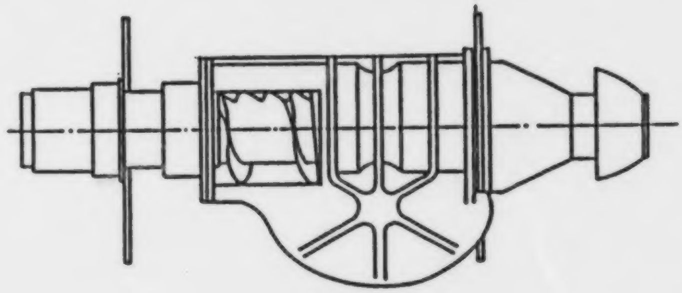
DIMENSIONS:
GT 185, PUMP UNIT

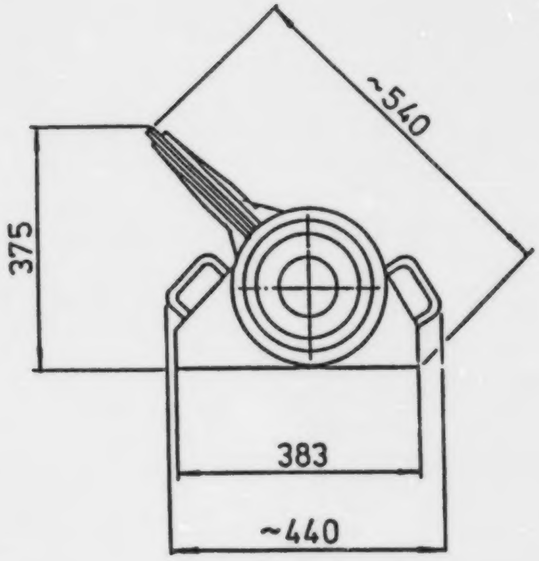
Dat.

Ritn.-nr

Océ-Ingul
A4-1,11
SMS 687


970
for 4 or 6"
discharge hose




~540
375
383
~440

This specification can be changed without notice.

Det.-nr	Ant.	Benämning	Material	Mod.-nr Ämne Dimension	Anm.

Konstr.	Ritad	Kop.	Kontr.	Stand.	Godk.	Skala	Ersätter	Ersatt av

DIMENSIONS

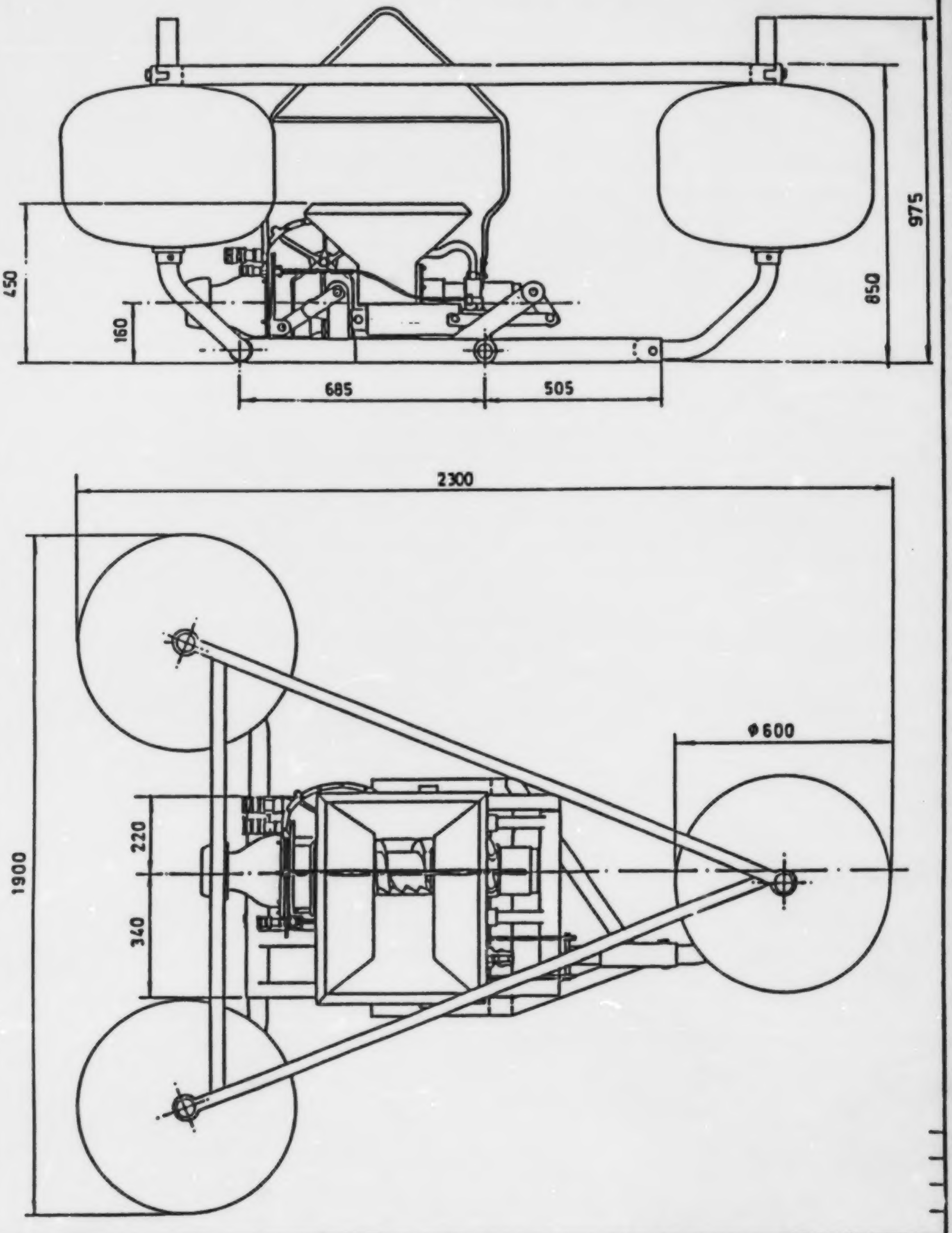
GT 185, PUMP UNIT

Det.

Ritn.-nr

enska
.11
687

Nr	Ant.	Ändring och/eller medd.-nr	Datum	Inf.	Godk.	10


975
850
450
160
685
505
2300
φ600
1900
220
340

Det.-nr	Ant.	Benämning	Material	Mod.-nr Ämne Dimension	Anm.

Konstr.	Ritad	Kop.	Kontr.	Stand.	Godk.	Skala	Ersätter	Ersatt av
	AJ							

GT 185 SKIMMER.

Måttskiss.

Dat. 840214

Ritn.-nr 41 G0342

nska
1
87

Use of the Light/Medium Oil Adapter

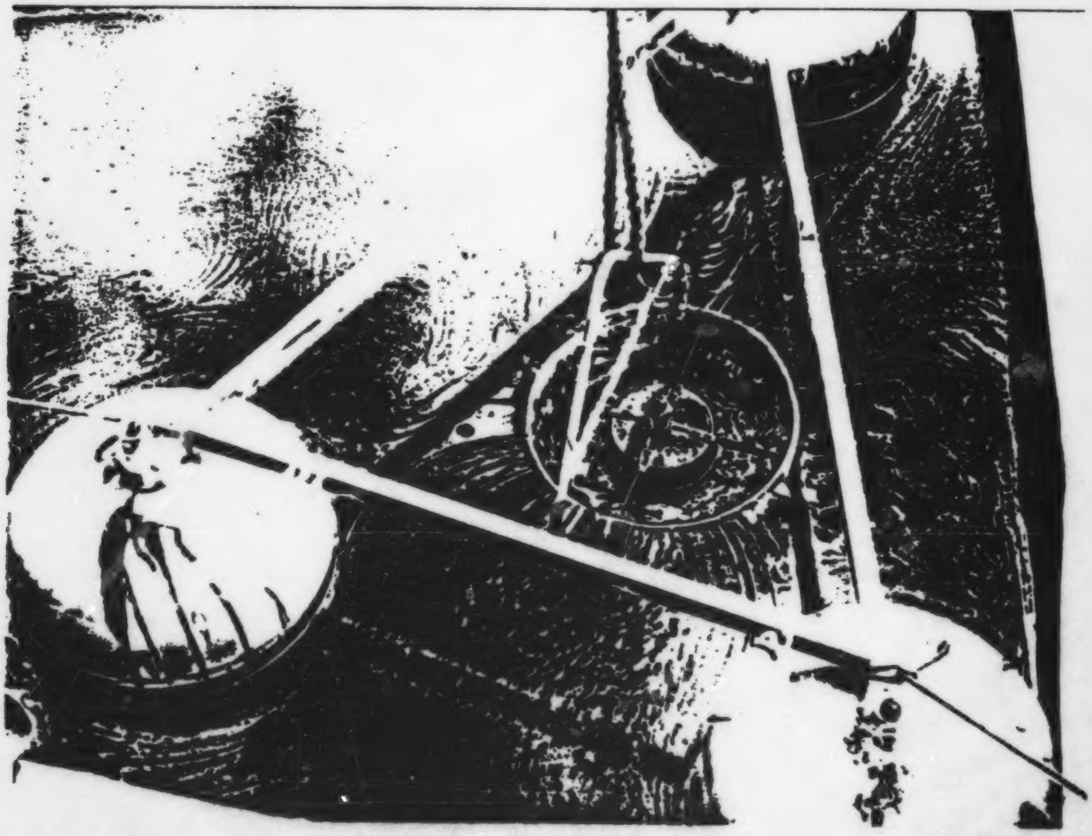
It is very important to understand and use the **Light/Medium Oil Adapter** which is included as a standard item with all **GT-260**, **GT-185** and **GT-185 ECONOMY** skimmers.

The Adapter is **always** to be used as long as the oil is in a fluid form. Heavy fuel oil No. 5 in + 3°C sea-water is still fluid enough for using the Light Oil Adapter

Although it is possible to skim relatively thin oil layers without the adapter, the use of the adapter will reduce the amount of water entering the skimmer with the oil resulting in a drastically increased recovery efficiency. The adapter will also help the pump to "draw" oil along the water surface allowing static operation of the skimmer in enclosed areas.

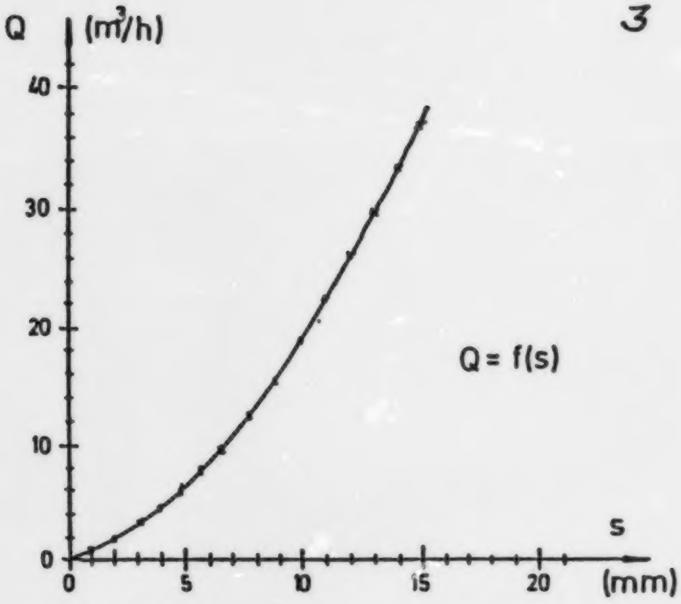
The adapter is easily fitted or removed from the hopper. A tight fit is obtained by using a rubber seal.

The adapter works automatically once the correct distance between the upper edge of the adapter has been correctly positioned in the oil layer. The correct distance is determined simply by adjusting the screw speed. The **Light/Oil Adapter** will permit unattended operation.

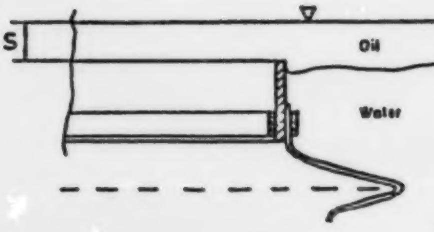


At slow pump speed only a relatively small amount of oil is needed to keep the hopper filled and the float is moving upward until balance between the oil entering and the oil beeing pumped away is established i.e., the slot between the edge of the hopper and the surface is closing thus allowing very thin oil layers to be skimmed. By increasing pump speed, the oil in the hopper will sink bringing along the float and the edge thereby opening the slot and allowing thicker oil layers to be skimmed.

The pump capacity depends on flow allowed by the gap S (fig 4.) The speed of the screw should be adjusted to this capacity according to the diagram (fig.3) Q = f (S) . . Q = Pump flow m^3/hr.



3



4

Copyright A B Pharos Marine Ltd.

Technical specification

WALOSEP W2

SKIMMER:

Dimension
L = W = 2000 mm, H = 1900 mm
(excl lifting rod = 1300 mm)

Draft
Normally = 750 mm
As overflow skimmer = 1000 mm

Weight
300 kg

Frame
Made of stainless steel SS 2333 and equipped with a weir system made of fiberglass-reinforced plastic

Rotor
Made of stainless steel SS 2333
The rotor is driven via gear wheels of bronze and plastic by a hydraulic motor Danfoss OMM 32
The speed of the rotor is variable between 0–25 rpm
Work speed 12–15 rpm
The hydraulic pressure is adjusted so that damages on the rotor are avoided
OMM 32: Pressure 40 bar
Flow = 3 l/min at 150 rpm
Efficiency = 0,25 kW

Stator
Made of oilresistant plastic. Outer diameter 800 mm

Floaters
Made of cellular plastic with a strong cover of GRP plastic.
The floaters can be set in different floating levels and serve at the same time as fenders

Cutterpump
Excenter screw pump NEMO NU 60 B completed with a cutting unit (optional)
The pump is driven by a hydraulic motor Danfoss OMS 80
Capacity 45 m^3/h at a counter pressure of max 6 bar

Cutterpump cont
OMS 80: Pressure 170 bar
Flow = 65 l/min at 800 rpm
Efficiency = 16 kW

Lifting equipment
The skimmer is equipped with a self-adjusting lifting rod

Hoses:

Hose from excenter screw pump
3" Cowerflex collapsible hose with quick connections and blind flanges
L = 10 m

Hydraulic hoses to and from cutterpump
2×10 m 1/2" SAE 100 R2A equipped with TEMA quick connections

Hydraulic hoses to and from rotor drive
2×10 m 3/8" Nylaflow Steelbraid equipped with TEMA quick connections

Technical design can be altered without notice.

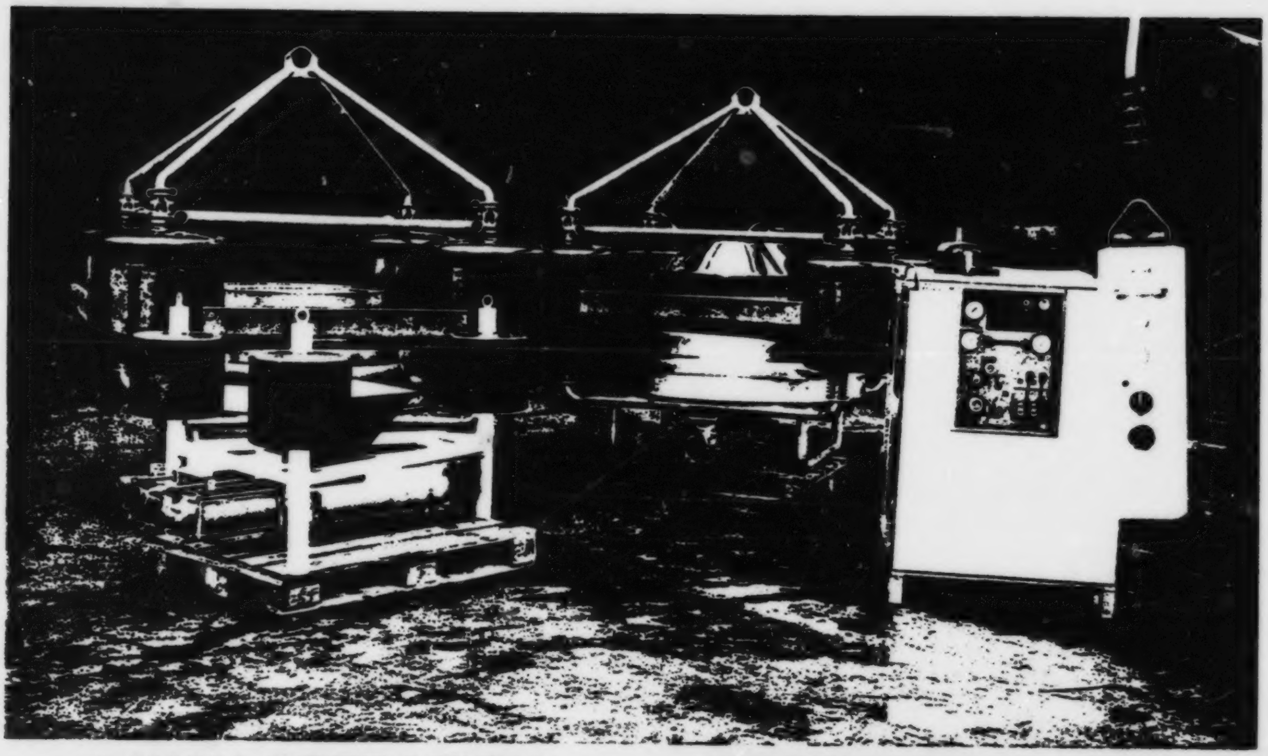
For further information and official test results, please contact

Mattssonprodukter

Postal address:
P.O. Box 692
S-451 24 UDDEVALLA
SWEDEN

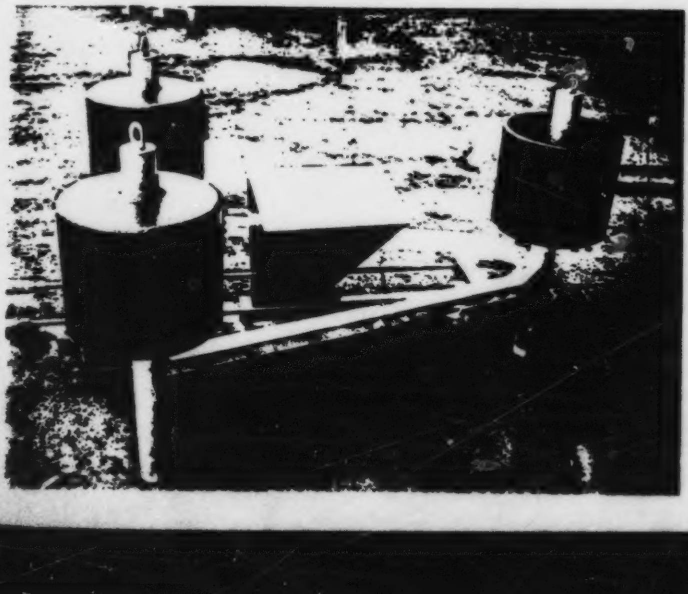
Phone + 46 522 983 00
Visiting address:
Junogatan 6
UDDEVALLA

Telex 42284 mpab s
Telefax
Nat 0522-385 02
Int +46 522 385 02



4-WAY OPERATION

NORMAL SKIMMER
OWERFLOW SKIMMER
TRANSFER PUMP →
FLOATING PUMP ↓



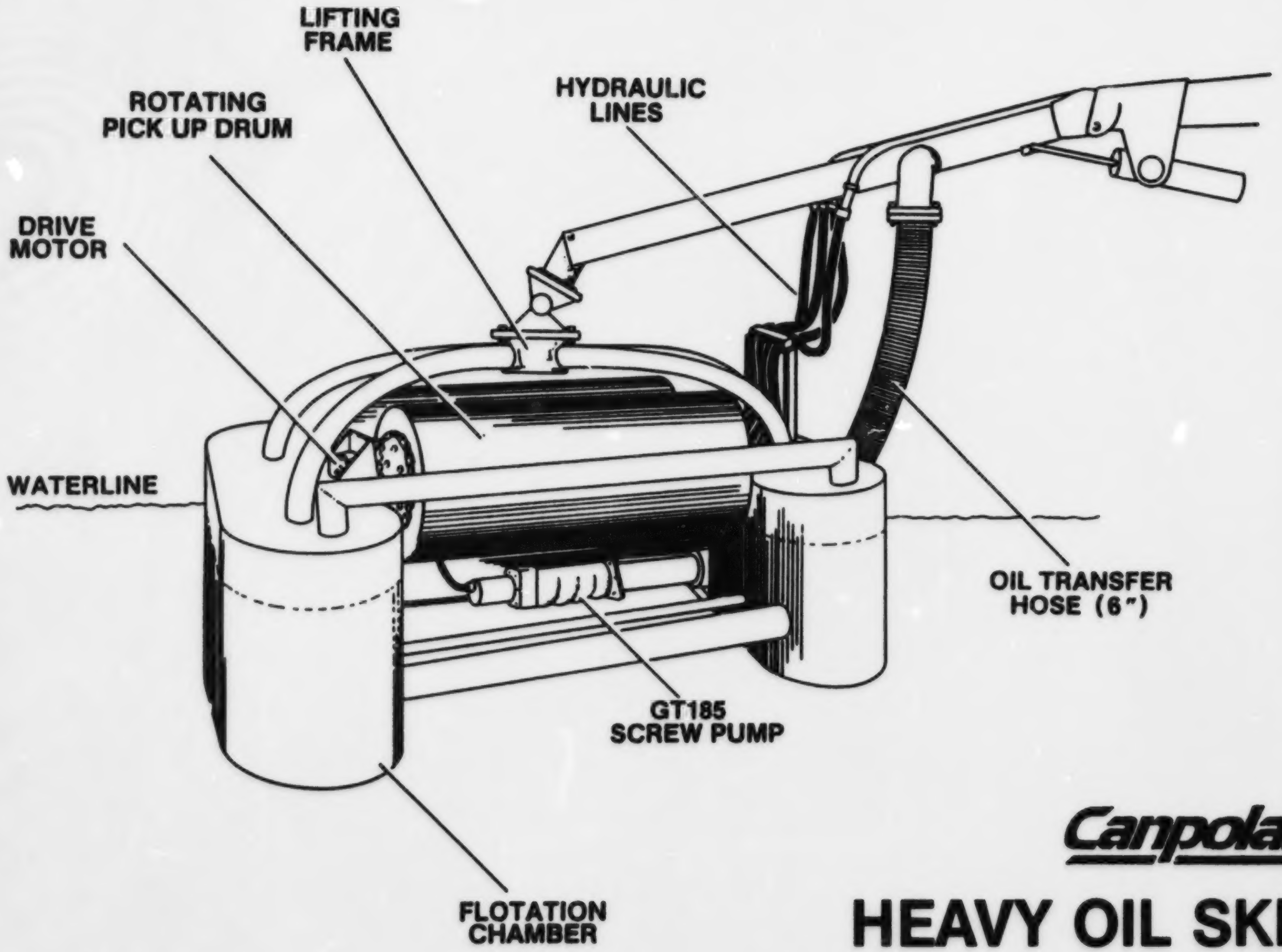
CANPOLAR HEAVY OIL SKIMMER

The Canpolar Heavy Oil Skimmer has been designed as a lightweight offshore skimmer suited for recovery of viscous oils such as Bunker-C. It has a nominal capacity of 40 tonnes per hour, weighs approximately one tonne, and can be deployed from a boom or as a free floating skimmer.

SPECIFICATIONS

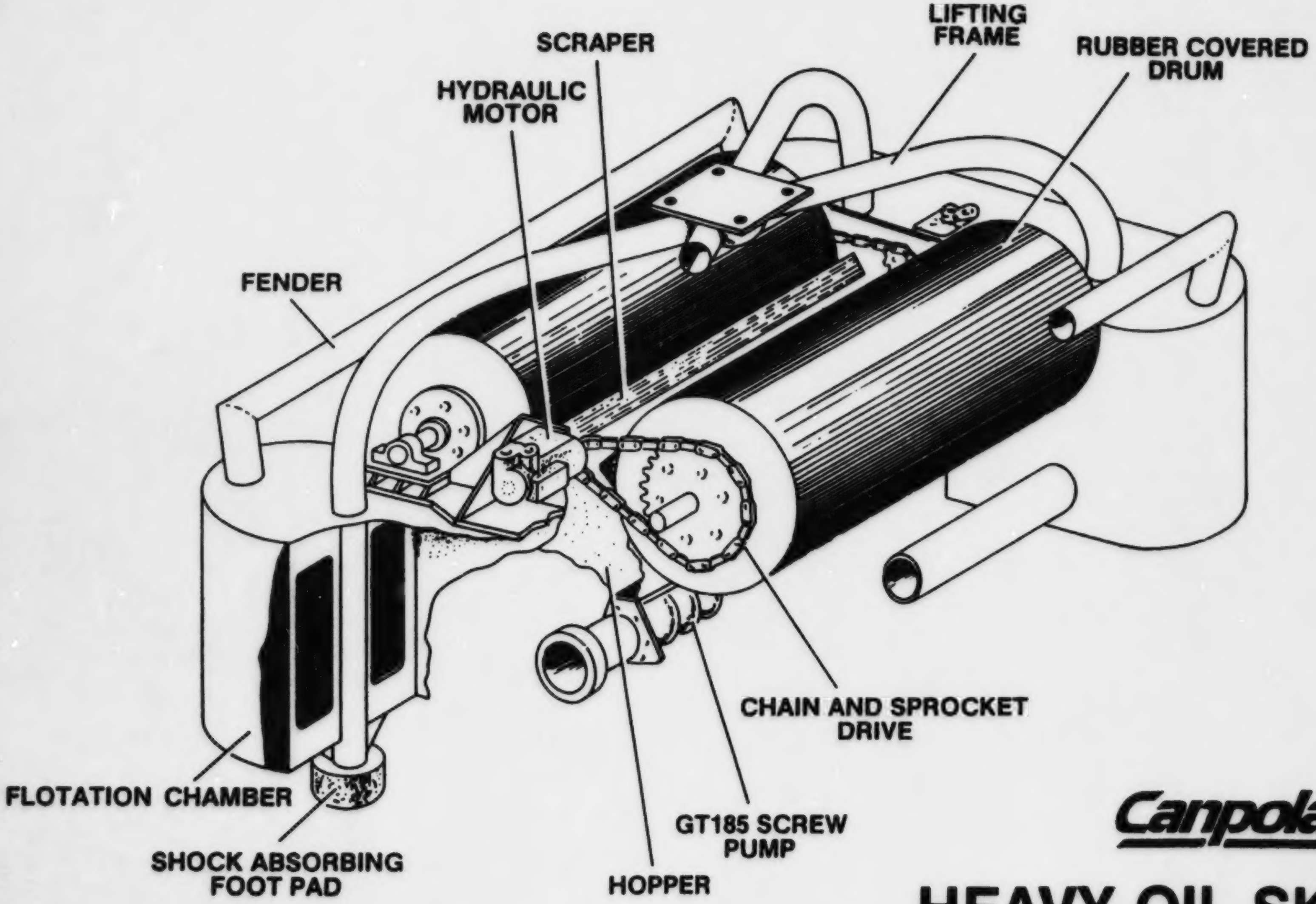
SKIMMING CAPACITY:	Nominal: 40 tonnes/hr. at 50,000 cP.
OUTSIDE DIMENSIONS:	2.0 m x 3 m x 1.3 m
GROSS WEIGHT (Dry):	725 kg + trimming ballast
HYDRAULIC POWER REQUIREMENTS:	Pump drive: 80L/min.; 140 bar Drum drives: 50L/min.; 140 bar
OIL TRANSFER LINE:	6"
CONSTRUCTION:	Body & frame: 6061 aluminum alloy Hopper shafting and drive chain: stainless steel. Motor casing, sprocket: mild steel
SKIMMING DRUMS:	Covering: HABASIT SAG 12E Dimensions: 0.6 m x 1.2 m Drive motors: CHAR-LYNN 4000 Hydraulic Motors Rotation: 1 rpm to 15 rpm, reversible
TRANSFER PUMP:	GT 185 screw pump: nominal capacity 44 tonnes/hr., 12 bar max pressure
BUOYANCY:	1800 kg total
VISCOSITY REDUCTION:	AMETEK Slurry Heater (optional)
OPERATION:	Tethered free floating or hydraulic arm suspension.

88-09-21


LIFTING FRAME
ROTATING PICK UP DRUM
HYDRAULIC LINES
DRIVE MOTOR
WATERLINE
OIL TRANSFER HOSE (6")
GT185 SCREW PUMP
FLOTATION CHAMBER

Canpolar Inc.

HEAVY OIL SKIMMER


SCRAPER
LIFTING FRAME
RUBBER COVERED DRUM
HYDRAULIC MOTOR
FENDER
CHAIN AND SPROCKET DRIVE
FLOTATION CHAMBER
GT185 SCREW PUMP
SHOCK ABSORBING FOOT PAD
HOPPER

Canpolar Inc.

HEAVY OIL SKIMMER

APPENDIX II

FLOWMETER SPECIFICATIONS

AND

CALIBRATION

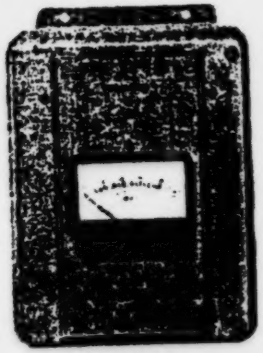
MODEL UFT-300

The Ultrasonic flow transmitter, indicator, totalizer systems are designed for use where a sensor cannot be installed in the process. The fluids must contain at least 25 PPM of suspended solids or bubbles which are at least 30 microns in size in order for the system to operate. The flow meter can be used as a unidirectional or bidirectional system with equal accuracy and repeatability. A signal strength light will link continuously when the minimum percent of suspended particles are present to give a reliable flow reading.

The Model UFT-301 has a resettable six (6) digit totalizer. It has a field selectable switch which allows the user to multiply the totalized volume measured by factors of 10, 100, 1,000, or 10,000. The Model UFT-300 has the same features as the UFT-301 except that is does not contain a totalizer.

The systems are supplied complete and ready to use. So easy to install, there is no system downtime for maintenance. The encapsulated waterproof design of the transducer sensor head can be easily mounted to the pipe surface with the clamp supplied with the unit. The fact that the systems are non-invasive means there is no head loss. A 15 ft. cable for connection to the transmitter/indicator units is supplied as an integral part of the sensor.

MODEL	DESCRIPTION
UFT-300	Transmitter/Indicator
UFT-301	Transmitter/Totalizer
T-500-HF	Transducer
S	GPM Scale



UFT-300
Transmitter/Indicator

UFT-301
Transmittter/Indicator/
Totalizer

APPLICATIONS:

- Waste water
- Slurries
- Crude Oils
- Hydraulic Oils
- Chemicals
- Coal Slurries
- Phosphates
- Fertilizers
- Acids
- Resins
- Process Waters

SPECIFICATIONS:

Range:	0 - 10 FPS (0.5 FPS min) GPM optional
Accuracy:	+/- 2 or 3% full scale
Linearity:	+/- 0.2% full scale
Repeatability:	+/- 0.2% full scale
Output:	4-20 mA into 600 ohms 0-1 mA into 2000 ohms
Power Supply:	120V AC +/- 10% 50/60Hz, 50mA or 12V/24V DC, 115mA
Sensitivity:	25 PPM of 30 micron particles

TRANSDUCER MODEL T-500-HF

For use with any Dynasonic Transmitter/Indicator/Totalizer; for permanent or portable installation.

Housing:	Aluminum; epoxy encapsulated
Cable:	15' standard, in flexible conduit w/plastic jacket
Service:	General Purpose
Temp. Range:	-40° to +180°F
Mounting Method	
Permanent:	Adjust. clamp & silicone rubber
Portable:	Clamp & silicone rubber or silicone grease

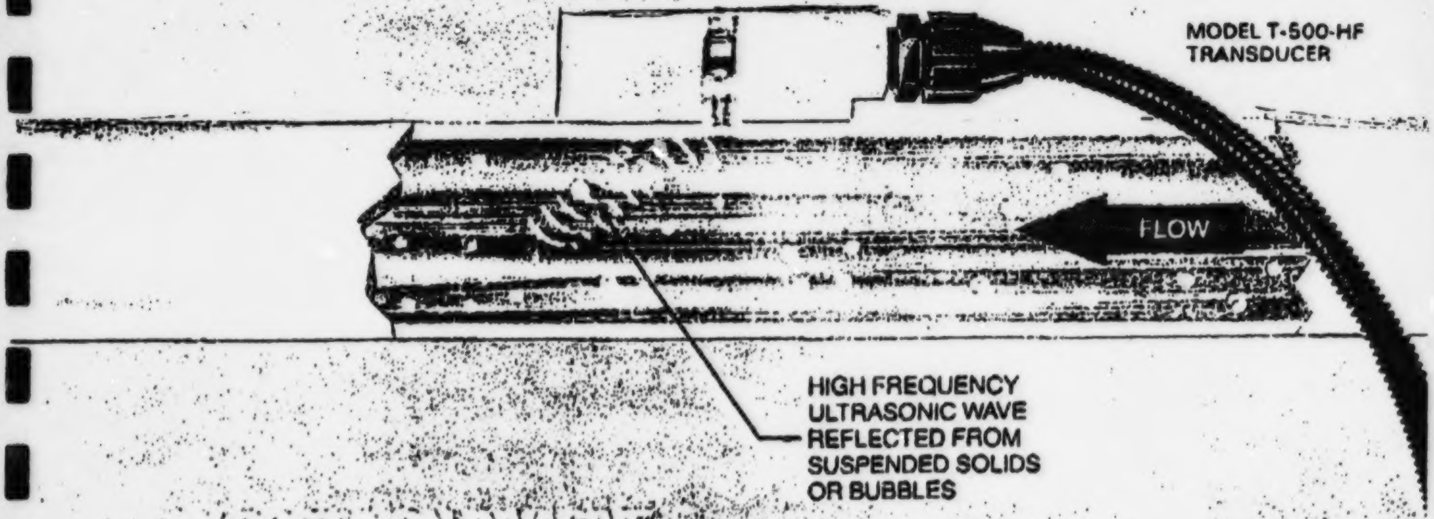
PIPE SIZE	MIN. FLOW (GPM)	SCALE (ft/s)	SCALE (GPM)
¾"	0.83	0-10	0-15
1"	1	0-10	0-25
1½"	3	0-10	0-75
2"	5	0-10	0-100
4"	20	0-10	0-400
6"	30	0-10	0-1000
8"	75	0-10	0-1500
10"	100	0-10	0-2500
12"	150	0-10	0-3500

To order unit with GPM scale, add suffix -S to model no., and specify range.

Minimum flow rate is 0.5ft/s for standard scale of 0-10ft/s.

Dynasonics, Inc.

BULLETIN #300 REV 1/85


MODEL T-500-HF
TRANSDUCER
FLOW
HIGH FREQUENCY
ULTRASONIC WAVE
REFLECTED FROM
SUSPENDED SOLIDS
OR BUBBLES

[illegible] COST, NONINVASIVE

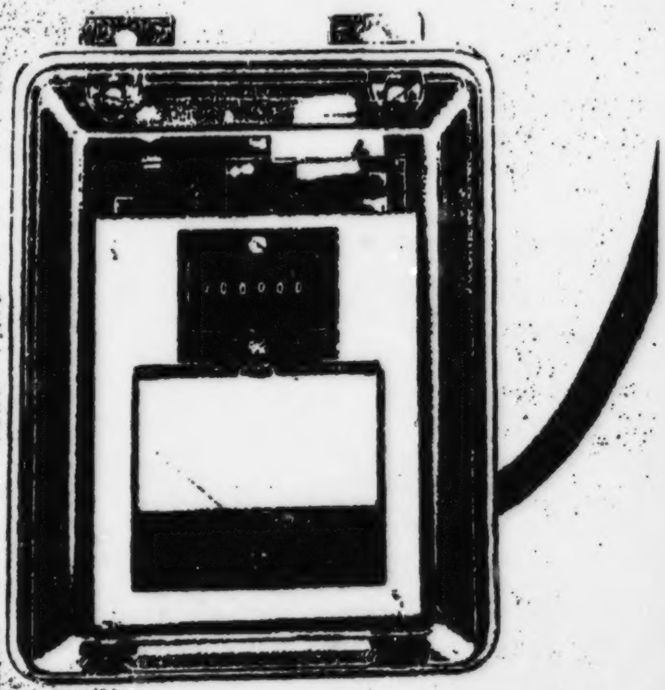
The Series 300 Flowmeter is the economy version of Dynasonic's highly successful high frequency 600 Series Flowmeter.

☐ Low Cost..........
☐ No Flow Obstruction..........
☐ Flows Down to 0.5 FPS Full Scale..........
☐ Slurries..........
☐ No Head Loss..........
☐ No Moving Parts..........
☐ Encapsulated Transducer..........
☐ No Maintenance..........
☐ Insensitive to Wide Range of Pressure and Temperature..........
☐ Optional Isolated 4-20ma output..........

[illegible]

☐ Acids..........
☐ Slurries..........
☐ Oils..........
☐ Coal Slurries..........
☐ Caustics..........
☐ High Pressure..........
☐ Pump Performance..........
☐ Waste Water..........
☐ Solvents..........
☐ Resins..........
☐ Food..........
☐ Low Flows..........
☐ Chemicals..........
☐ Pharmaceuticals..........

MODEL UFT-301-S
TRANSMITTER



TRANSDUCER

T-500-HF Transducer

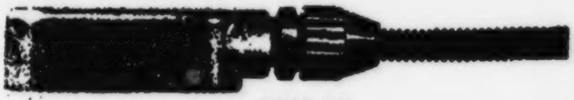
Application: For permanent or portable installation of Dynasonic system for use with any Dynasonic Transmitter/Indicator/Totalizer or Flow Switch.

Housing Material	Aluminum; Epoxy Encapsulated.
Cable	15 feet (4.57 meters) standard, in flexible conduit with plastic jacket.
Service	General purpose.
Temperature Range	− 40° to + 180°F (− 40°C to + 82°C), extended temperature range available, see T-500-HT.
Mounting Method	Permanent—Adjustable clamp & epoxy adhesive. Portable—clamp & silicone rubber or silicone grease.

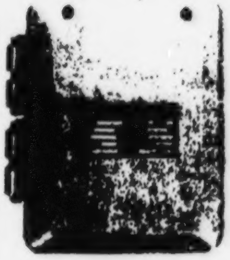
T-500-HT-HF Transducer

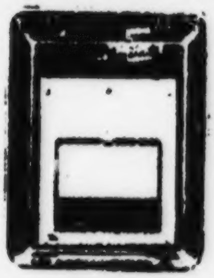
Application: For high temperature locations for permanent or portable installation of Dynasonic system for use with any Dynasonic Transmitter/Indicator/Totalizer or Flow Switch.

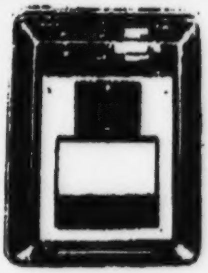
Temperature Range	− 40°F to + 300°F (− 40°C to + 148°C)


T-500-HF

TRANSMITTER/INDICATORS/TOTALIZERS


UFT-300B
Transmitter Only


UFT-300
Transmitter/Indicator


UFT-301
Transmitter/Indicator/Totalizer

OPERATION

To operate, hold or clamp transducer on any metal or plastic pipe, one inch or larger. Acoustic coupling material or grease (supplied), must be used between transducer and pipe. Liquid in pipe should have at least 25 PPM 30 micron or larger, of suspended solids or bubbles for operation. Certain pipe conditions require more suspended solids. Field calibration on flow allows calibration for solids greater than 2% or lined pipe if required. The best accuracy of permanently mounted transducer is typically obtained below 3% suspended solids. (Refer to application data sheet for recommendations.)

UFT-300 Series

Indicator Range	Standard: 0-10 feet/sec (0.5 feet/sec min) except UFT-300B.
Optional Output	4-20ma into 600 ohms max., isolated.
Enclosure	NEMA IV; Fiberglass
Enclosure Size	8¾" H x 6¾" W x 5" D
Power Input	120 VAC, ± 10%, 50/60 Hz or 12 VDC, 7 watts.
Signal Strength Light	Indicates sufficient solids for operation.
Temperature	− 20° to + 120°F.*
Totalizer	UFT-301 only—6 digit.
Low Flow Option	0.5 FPS FS to 2.5 FPS FS (Add-LF)

*Except indicating meter to 32°F

FLOW SWITCH

FS-300 Flow Switch *(Below 2.5 FPS Full Scale select Low Flow-LF)*

Application	Provides switching on various flow velocities
Switch and Rating	DPDT, 5 amp, 115 VAC, resistive load.
Power Input	120 VAC, 50/60 Hz or 12 VDC
Switch Adj.	1 to 15 feet/sec.*
Time Delay	2 sec to 20 sec; adjustable on low flow
Fail Safe	Switch contacts in de-energized mode on low flow.
Operating Liquids	Same requirements as flowmeters.
Enclosure	NEMA IV; Fiberglass.
Enclosure Size	8¾" H x 6¾" W x 5" D.

*Adj. down to 0.1 feet/sec. on - LF model.
**Will operate with any liquid at pump discharge

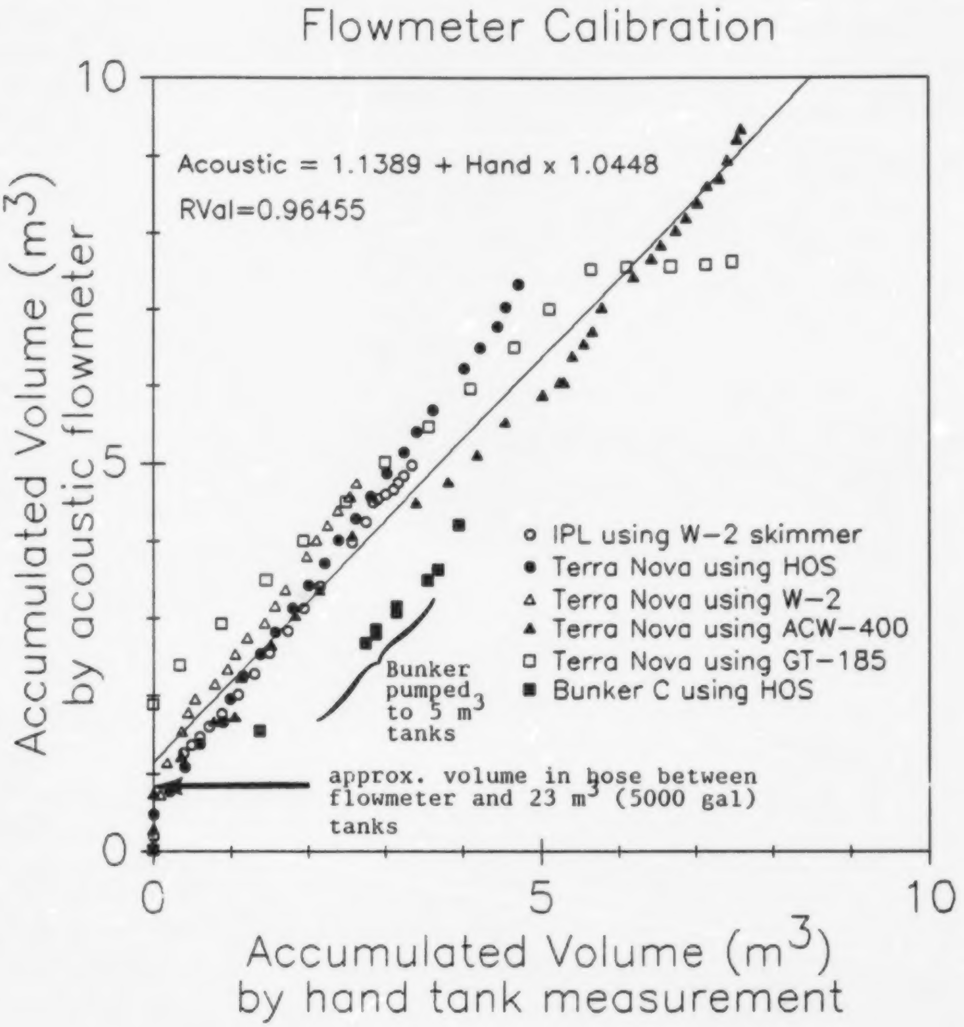
Dynasonics, Inc.

Mannion's
PUMP HOUSE
AND ELECTRIC MOTOR REPAIRS

RAYMOND FARLEY
Engineered Sales

848 CLYDE AVENUE
OTTAWA, ONT. K1Z 5A2

BUS. (613) 722-4226
FAX (613) 722-7895


Flowmeter Calibration
Acoustic = 1.1389 + Hand x 1.0448
RVal=0.96455
○ IPL using W-2 skimmer
● Terra Nova using HOS
△ Terra Nova using W-2
▲ Terra Nova using ACW-400
□ Terra Nova using GT-185
■ Bunker C using HOS
Bunker pumped to 5 m^3 tanks
approx. volume in hose between flowmeter and 23 m^3 (5000 gal) tanks
Accumulated Volume (m^3) by acoustic flowmeter
Accumulated Volume (m^3) by hand tank measurement
0
5
10
0
5
10

APPENDIX III

ANALYTICAL PROCEDURES AND CALCULATIONS

ANALYTICAL PROCEDURES

The emulsion samples were analysed on site for free water, emulsified water, density and viscosity. Analysis was performed using the following procedures:

i) % Free Water (vol.): The percentage of free water in the recovered fluid was determined by settling. After a 10 to 20 minute settling period, the free water to total fluid ratio was measured visually to give the volume percentage of free water. Volumes were measured in the sampling bottle using a flexible rule calibrated to measure units of volume for this particular type of bottle.

ii) % Emulsified Water (mass): the mass percentage of emulsified water was determined by spectrophotometry. Extracted samples were compared to standards of known oil concentrations. The experimental method was as follows:

1. Weight out 1.0g of oil emulsion;
2. add the oil sample along with 25 mL of toluene to a separatory funnel, shake well and let stand 30 minutes;
3. Decant and discard separated water;
4. Decant and record volume of remaining oil/toluene mixture;
5. Determine the oil concentration in grams of oil per litre of toluene by spectroscopy using a known standard; and
6. Calculate the "% emulsified water" in the original sample.

Sample calculations for emulsified water are appended.

iii) Density: the emulsion density was determined gravimetrically using calibrated, preweighed 10 mL density vials.

iv) Viscosity: viscosity was determined by timed flow at constant temperature of the oil sample through a viscometer. Ubeholde (#100, #200) and Standard cross–arm (#6–#8) viscometers were used for this determination. Temperature was kept constant by immersing the viscometers in a water bath.

All glassware was cleaned with an alternate rinse of toluene and acetone.

EMULSIFIED WATER CALCULATIONS

The following equations were used to calculate the mass percent water in emulsion samples.

Mass of oil in emulsion sample, M (g):

$$M = (R)\ (D/S)\ (E/1000) \tag{1}$$

where:

M, (g) = Oil mass in sample

R, (g/L) = Spectrophotometer concentration reading

E, (mL) = Extraction solvent volume (initial oil/toluene mixture)

S,(mL) = Spectrophotometer solvent volume (a quantity of the initial oil/toluene mixture)

Mass percent water, W:

$$W = (1 - M/m) \times 100 \tag{2}$$

where: m, (g) = Mass of emulsion sample, 1.0g

Sample calculation using data for Bunker C:

$E = 25$ mL

$S = 0.5$ mL

$D = 20$ mL

$R = .5720$ g oil/L toluene

$M = 1.0$

Therefore,

$$M = \frac{(.5720)\ (20)\ (25)}{(.5)\ (1000)}$$

$$M = 0.527$$

and $W = (1 - 0.527/1.0) \times 100$

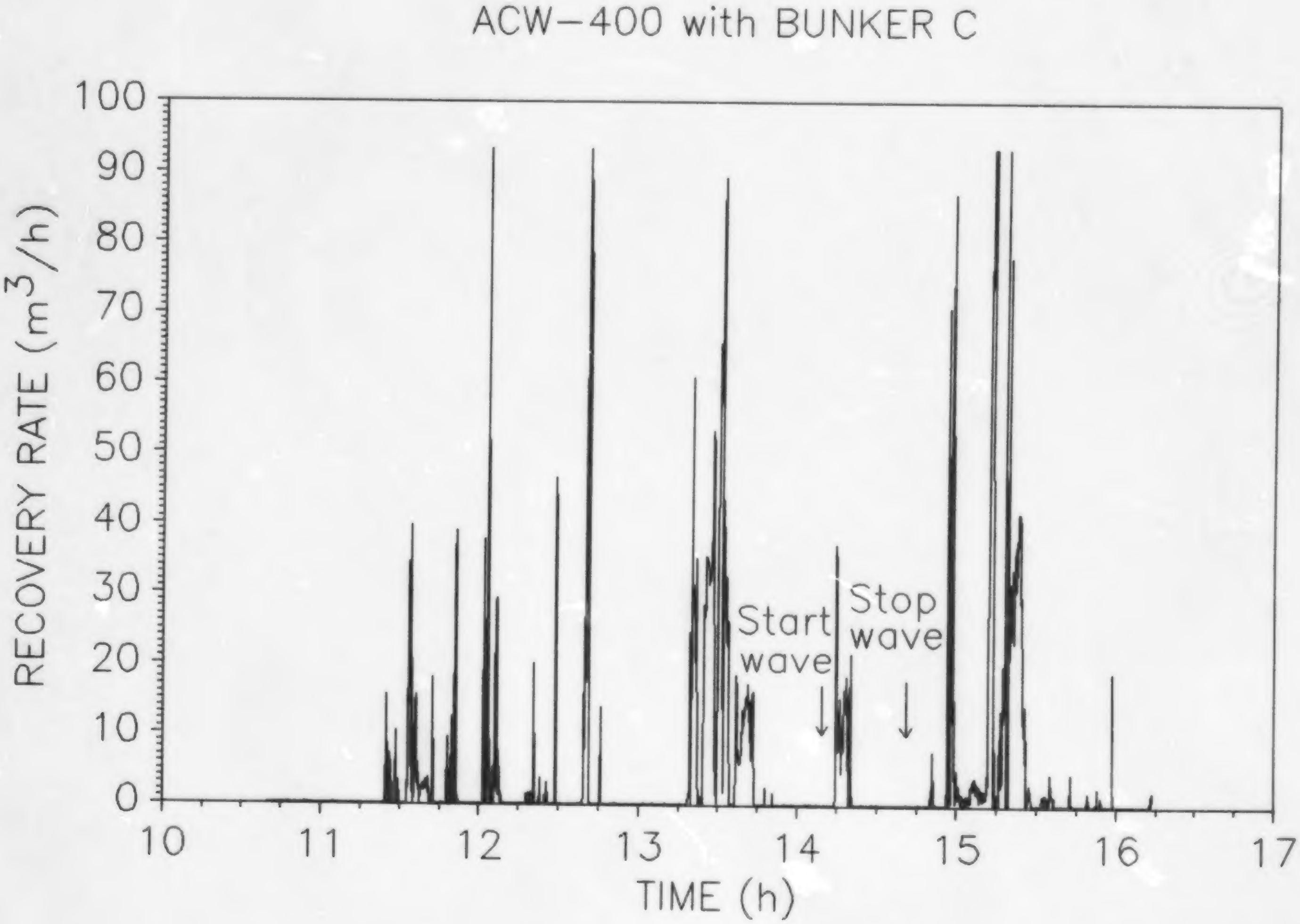
$W = 47.3$ mass % water

APPENDIX IV

SKIMMER RAW DATA

AND

FIELD NOTES


ACW-400 with BUNKER C
RECOVERY RATE (m^3/h)
0
10
20
30
40
50
60
70
80
90
100
TIME (h)
10
11
12
13
14
15
16
17
Start wave
Stop wave

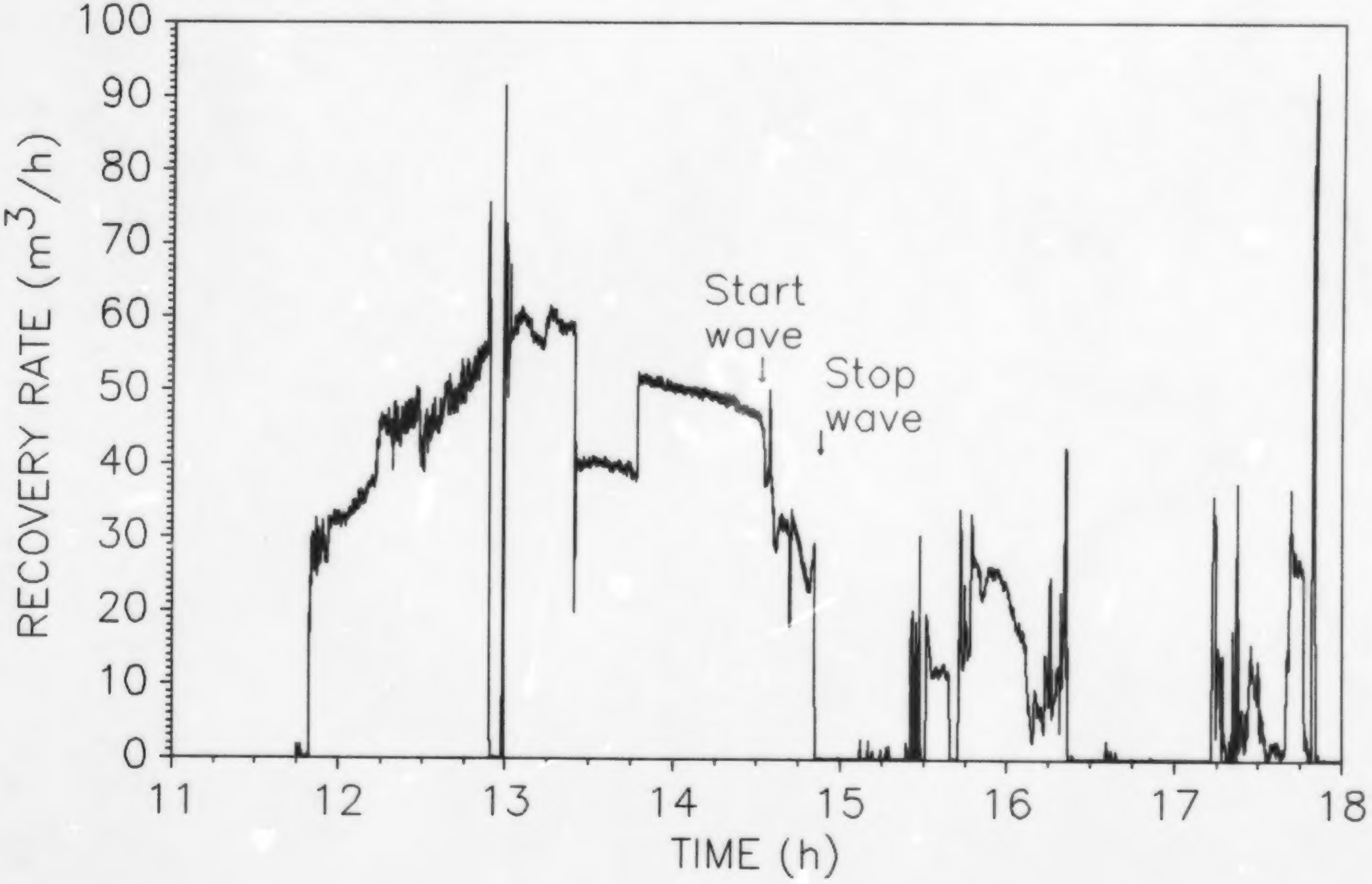
CHRONOLOGY — TEST #2

SKIMMER: FRAMO ACW-400
OIL: BUNKER "C"

DATE: 28/09/88
WATER T (°C) = 18
AIR T (°C) =
OIL VOL. (m^3) = 4
= 69 mm

APPROXIMATE TIME OF DAY	WAVES			SKIMMER			COMMENTS
	H (m)	T (s)	L (m)	DISC	WEIR	PUMP	
11:39	0	0	0	0	up		commence tests
12:39	0	0	0	10 rpm	up	140 bar	
12:50	0	0	0	10	up	140	steam siphon on
13:00	0	0	0	0	0	0	stop
13:45	0	0	0	10	up	140	restart
14:05	0	0	0	10	up	140	
14:10	—	—	—	2	up	135	start waves, oil slowing discs
14:20	0.5	4	18	2	up	135	skimmer pushing oil away and under boom
14:30	0	0	0	0	0	0	stop waves and skimmer
15:00	0	0	0	—	down	140	pump to slops
15:15	0	0	0	—	down	140	steam siphon on
15:40	0	0	0	—	down	140	thin slick only left

ACW–400 with IPL Sweet

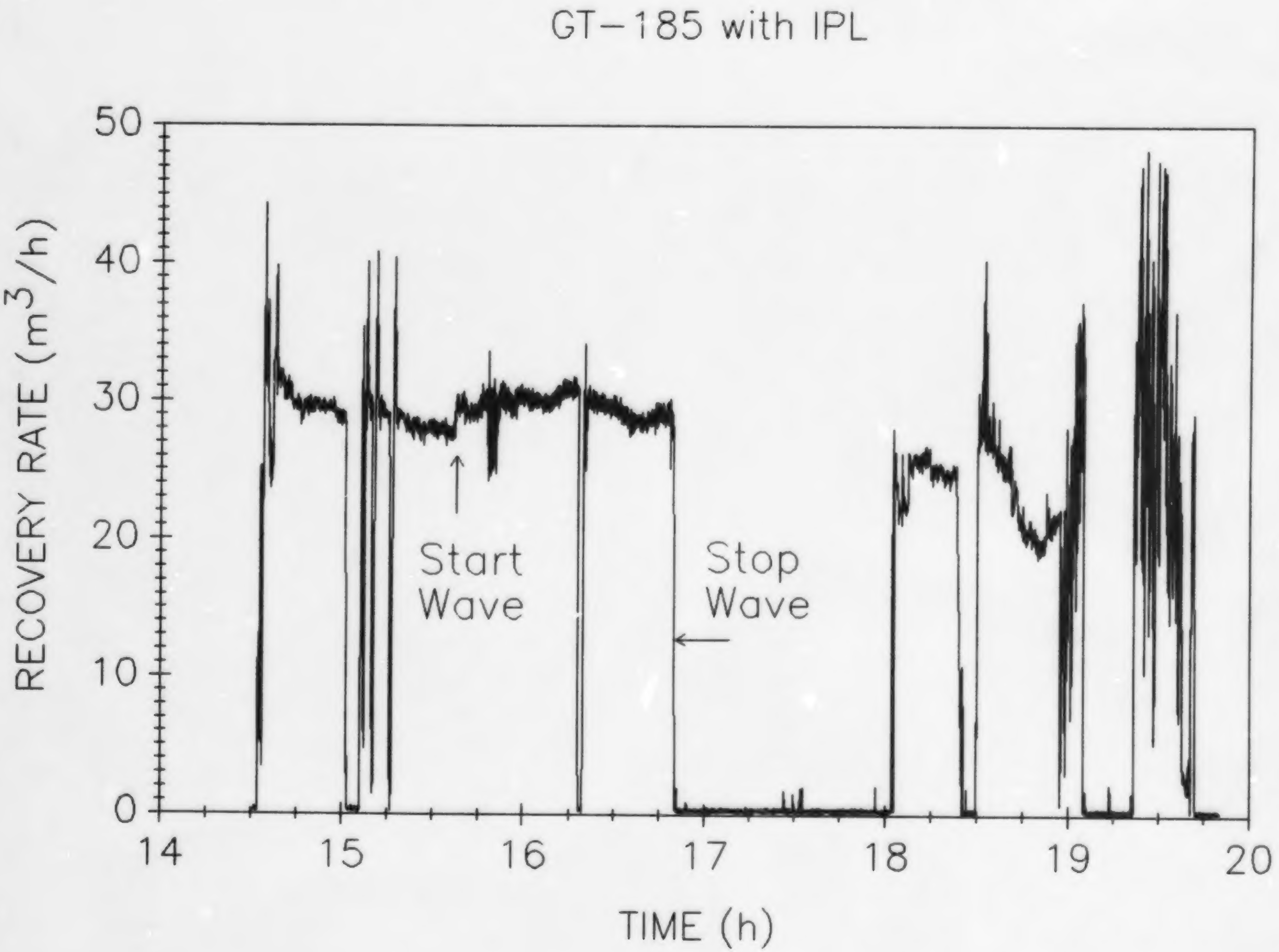


CHRONOLOGY — TEST #3

SKIMMER: FRAMO ACW-400
OIL: IPL Sweet

DATE: 29/09/88
WATER T (°C) = 17
AIR T (°C) =
OIL VOL. (m^3) = 2.68
= 47 mm

APPROXIMATE TIME OF DAY	WAVES H (m)	WAVES T (s)	WAVES L (m)	SKIMMER DISC	SKIMMER WEIR	SKIMMER PUMP	COMMENTS
11:35	0	0	0	0	0	0	start
11:51	0	0	0	10 rpm	up	50 bar	skimmer emulsifys oil
11:57	0	0	0	10	up	50	steady state
12:15	0	0	0	15.6	up	40	increase discs
12:35	0	0	0	17.1	up	45	increase discs
12:50	0	0	0	0	—	0	stop to adjust weir
13:00	0	0	0	17.1	– 5 cm	50	restart
13:25	0	0	0	10.3	up	40-50	weir up, slow discs
13:45	0	0	0	15.75	up	40	increase discs
13:49	0	0	0	15.75	up	50	increase pump
14:30	0	0	0	15.75	up	50	no change
14:35	—	—	—	15.75	up	50	start waves
14:45	0.5	4	17	15.75	up	50	
14:50	—	—	—	0	—	0	stop test, skimmer pushing oil under booms


GT-185 with IPL
RECOVERY RATE (m^3/h)
0
10
20
30
40
50
14
15
16
17
18
19
20
TIME (h)
Start
Wave
Stop
Wave

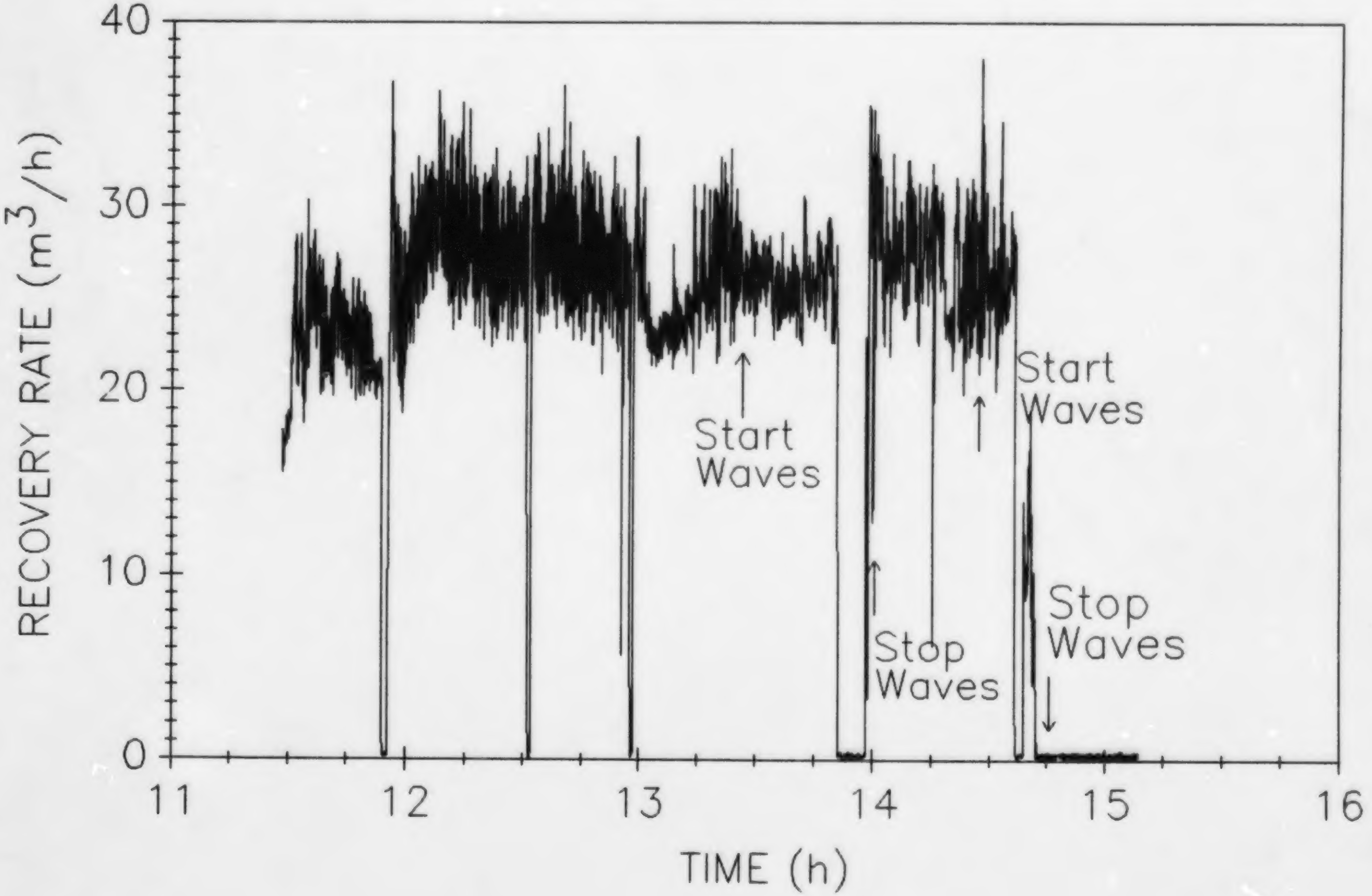
CHRONOLOGY — TEST #4

SKIMMER: GT-185
OIL: IPL Sweet

DATE: 30/09/88
WATER T (°C) = 18
OIL T (°C) = 16
OIL VOL. (m^3) = 2.68

APPROXIMATE TIME OF DAY	WAVES H (m)	T (s)	L (m)	SKIMMER DISC	WEIR	PUMP	COMMENTS
14:30	0	0	0	N/A	0	0	skimmer in
14:35	0	0	0		—	—	adjusting weir
14:42	0	0	0		– 2 cm	6 + @850 psi @2500 rpm	very little emuls.
14:55	0	0	0		"	800 psi	
15:00	0	0	0		—	0	adjust weir dam
15:10	0	0	0		—	—	still adjusting
15:20	0	0	0		– 4 cm	6 + @700 psi 2500 rpm	little emuls., oil getting more viscous
15:30	0	0	0		"	"	
15:37	—	—	—		"	"	waves on
15:45	0.58	4	20		– 1 cm	"	weir up
16:02	0.56	4	20		"	"	some emuls.
16:20	—	—	—		—	—	adjusting weir; out of water
16:23	0.5	4	20		– 1 mm	"	
16:45	0.4	4	20		"	775 psi	
16:50	0.75	4	20		"	"	stop for Elastol
18:00	0	0	0		"	750 psi	restart
18:07	0	0	0		"	"	
18:10	0	0	0		– 1 cm	"	drop weir
18:15	—	—	—		"	"	waves on
18:30	—	—	—		—	—	stop test, pump to slops, steam siphon on
18:45	0	0	0		-1^+ cm	"	adjust weir dam
18:58	0	0	0		"	"	water over weir
19:30-19:45	0	0	0		– 5 cm	"	pump water

GT – 185 with Bunker C

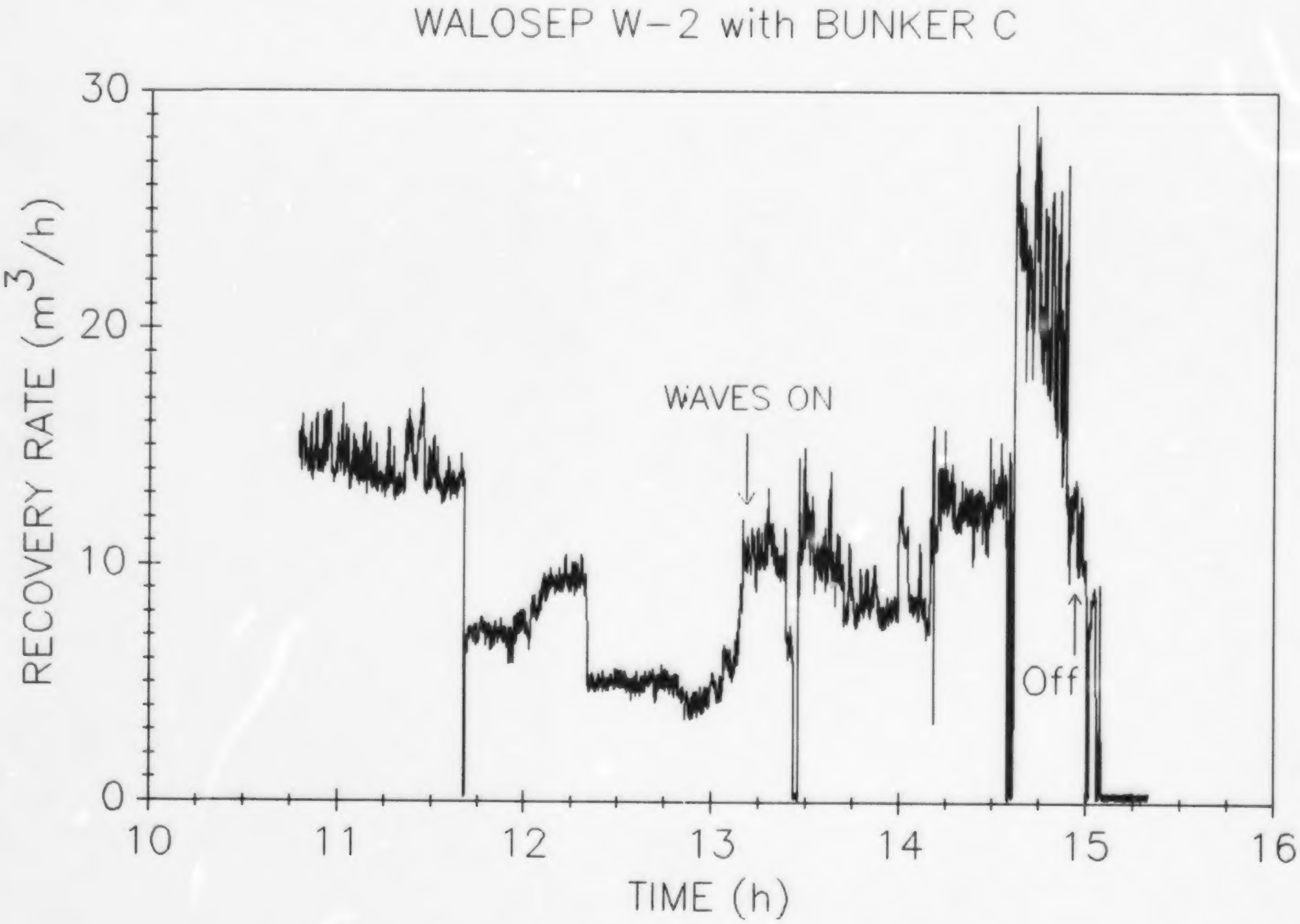


CHRONOLOGY — TEST #5

SKIMMER: GT-185
OIL: BUNKER "C"

DATE: 01/10/88
WATER T (°C) = 18
OIL T (°C) = 27
OIL VOL. (m^3) = 4
= 69 mm

APPROXIMATE TIME OF DAY	WAVES H (m)	T (s)	L (m)	SKIMMER DISC	WEIR	PUMP	COMMENTS
11:26	0	0	0	N/A	0	0	start; adjust
11:28	0	0	0		− 2 cm	6 + @700 psi 2100 rpm	adjust pump
11:44	0	0	0		− 3 cm	850 psi	drop weir
11:51	0	0	0		"	800 psi @2500 rpm	
12:04	0	0	0		"	"	adjust weir
12:07	0	0	0		− 4 cm	"	
12:45	0	0	0		"	700 psi	
13:05	0	0	0		− 3 cm	"	adjust weir
13:10	0	0	0		"	"	start steam siphon
13:15	0	0	0		"	"	
13:20	0	0	0		"	"	ΔT = 72 ► 80°F
13:27	—	—	—		"	"	waves on
13:33	0.42	4	—		"	"	weir periodically flooding
13:36	0.7	4	—		"	"	waves incr.
13:44	0.57	4	20		− 6 cm	"	adjust weir
14:00	0	0	0		—	0	remove light oil adapter
14:10	0	0	0		− 3 cm	6 + @700 psi @2600 rpm	L.O.A. off
14:23	0.4	4	20		"	"	waves on
14:33	0.38	4	20		"	"	
14:45	0	0	0		"	"	stop


WALOSEP W-2 with BUNKER C
RECOVERY RATE (m^3/h)
0
10
20
30
TIME (h)
10
11
12
13
14
15
16
WAVES ON
Off

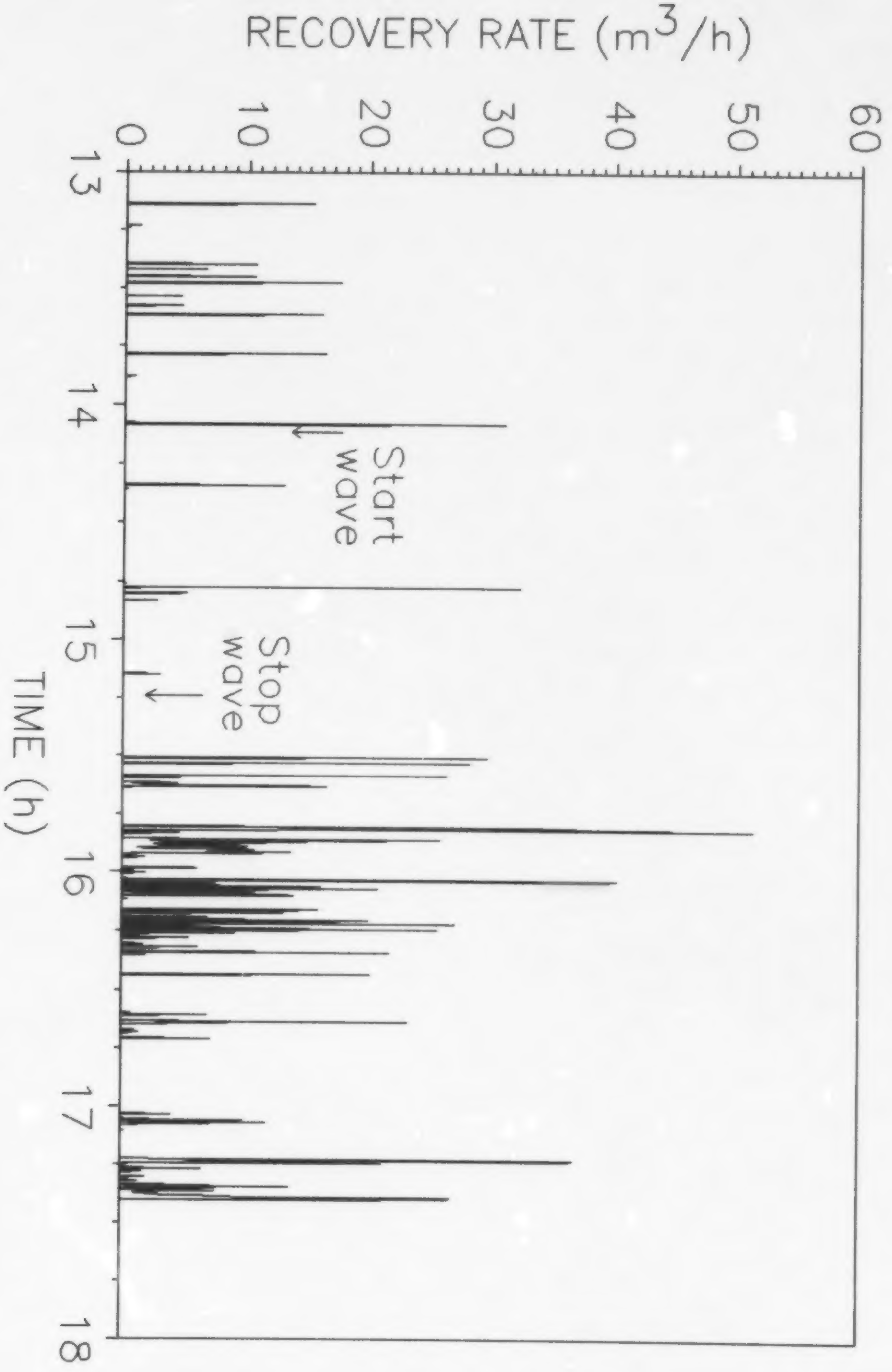
CHRONOLOGY — TEST #6

SKIMMER: WALOSIP W-2
OIL: BUNKER "C"

DATE: 03/10/88
WATER T (°C) = 17
OIL T (°C) = 14
OIL VOL. (m³) = 4
= 69 mm

APPROXIMATE TIME OF DAY	WAVES H (m)	T (s)	L (m)	SKIMMER ROTOR	WEIR	PUMP	COMMENTS
10:48	0	0	0	12-13 rpm	– 5 cm	3½ @ 150 bar	start
11:12	0	0	0	11.5-12.5	"	"	reduce rotor slightly
11:47	0	0	0	16	"	2½	adjust pump and rotor
12:00	0	0	0	12	"	"	adjust rotor
12:20	0	0	0	12	"	2	reduce pump
13:00	0.32	4.2	20	"	"	"	waves on
13:12	0.6	4.2	20	"	"	"	
13:15	0.73	4.2	20	"	"	"	
13:30	0.5	4.12	20	"	"	2½	increase pump
13:42	0.44	3.99	20	"	"	"	
14:00	0.48	4.0	20	"	"	"	
14:01	"	"	"	"	"	3	increase pump
14:10	0.45	3.8	20	"	"	2½	decrease pump then increase to 2¾
14:25	0.48	4.0	20	"	"	2¾	— oil slick in discontinuous chunk — moving skimmer no help — chunks drawn in by rotor
1440	0.58	3.9	20	"	"	"	
1455	0.68	3.9	20	"	"	"	stop

Heavy Oil Skimmer with BUNKER C

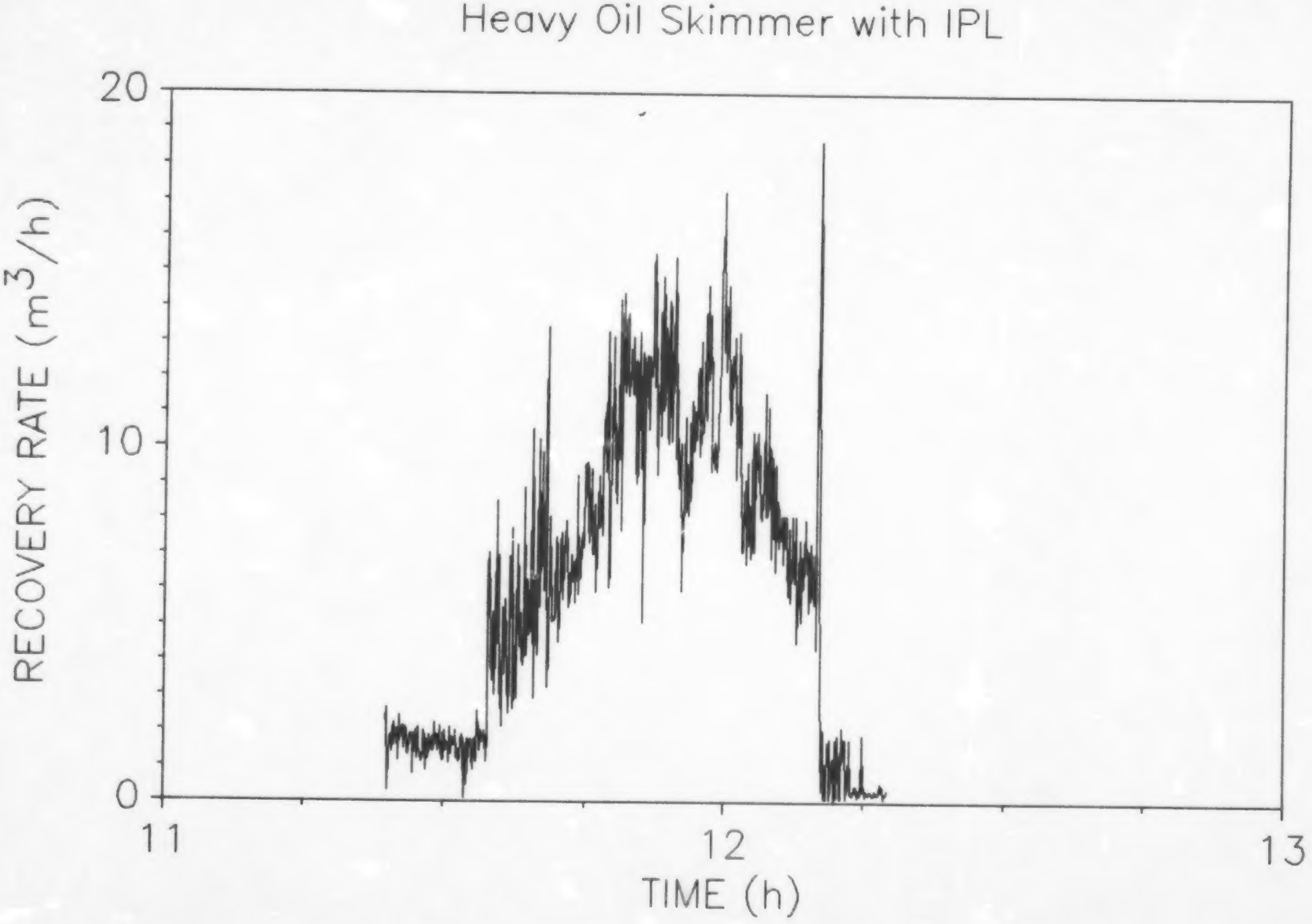


CHRONOLOGY — TEST #7

SKIMMER: H.O.S.
OIL: BUNKER "C"

DATE: 04/10/88
WATER T (°C) = 17
OIL T (°C) =
OIL VOL. (m^3) = 4
= 69 mm

APPROXIMATE TIME OF DAY	WAVES			SKIMMER			COMMENTS
	H (m)	T (s)	L (m)	DRUM	WEIR	PUMP	
13:07	0	0	0	—	N/A	0	skimmer in
13:18	0	0	0	—		—	start pump — no recovery
13:28	0	0	0	various – ve		intermittent	running in reverse at various settings — no recovery
13:45	0	0	0	"		"	push skimmer down — no recovery
13:47	0	0	0	various + ve		"	drum rotating as designed — no recovery
13:50	0	0	0	"		"	push skimmer down more — pontoons just underwater
14:01	0	0	0	"		"	let skimmer float
14:07	—	—	—	"		"	waves on
14:43	0.4	4	20	various – ve		"	no recovery
15:15	0	0	0	"		"	Elastol added
15:36	0	0	0	0		0	tighter — some scrapers recovery
15:45	0	0	0	+ ve		intermittent	start steam siphon
15:53	0	0	0	+ ve 30 rpm		intermittent	



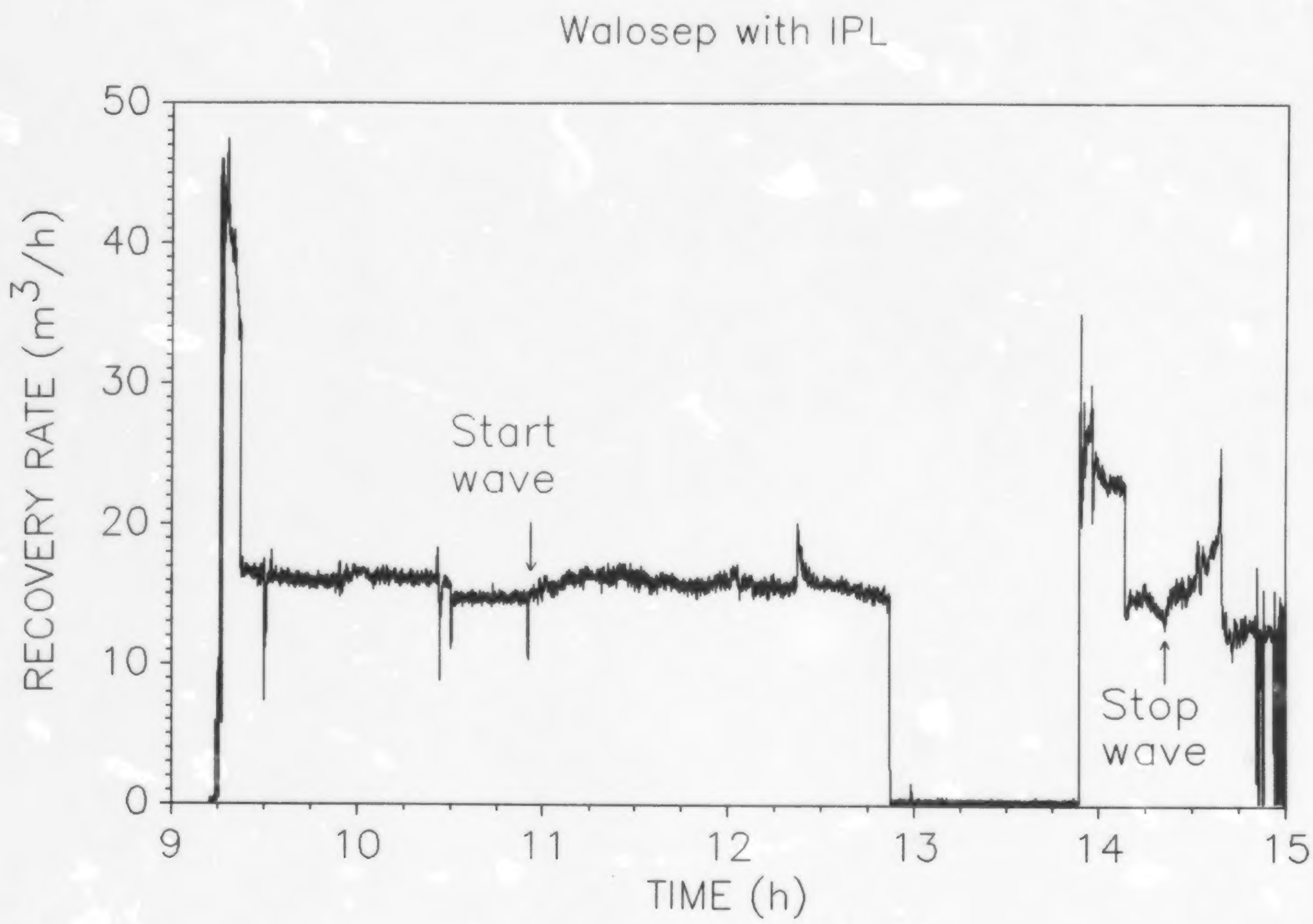
Heavy Oil Skimmer with IPL

CHRONOLOGY — TEST #8

SKIMMER: H.O.S.
OIL: IPL Sweet

DATE: 05/10/88
WATER T (°C) = 16.5
OIL T (°C) = 18
OIL VOL. (m^3) = 2.60

APPROXIMATE TIME OF DAY	WAVES			SKIMMER			COMMENTS
	H (m)	T (s)	L (m)	DRUM	WEIR	PUMP	
09:53	0	0	0	15 rpm + ve	N/A	—	start — no recovery
09:57	0	0	0	0		0	stop (loosen scraper blades)
10:07	0	0	0	12 rpm + ve		—	start — no recovery
10:18	0	0	0	0		—	stop test
10:57	0	0	0	0		0	Elastol added
11:13-11:31							waves on to mix
11:33	0	0	0	—		—	restart skimmer
11:35	0	0	0	15 rpm + ve		40 bar	
11:41	0	0	0	10 rpm + ve		"	slow drum rot.
11:59	0	0	0	7.5 rpm + ve		"	slow drum rot.
12:04	0	0	0	15 rpm + ve		"	speed up drum — oil not adhering
12:08							— reverse drums — no oil in sump — stop



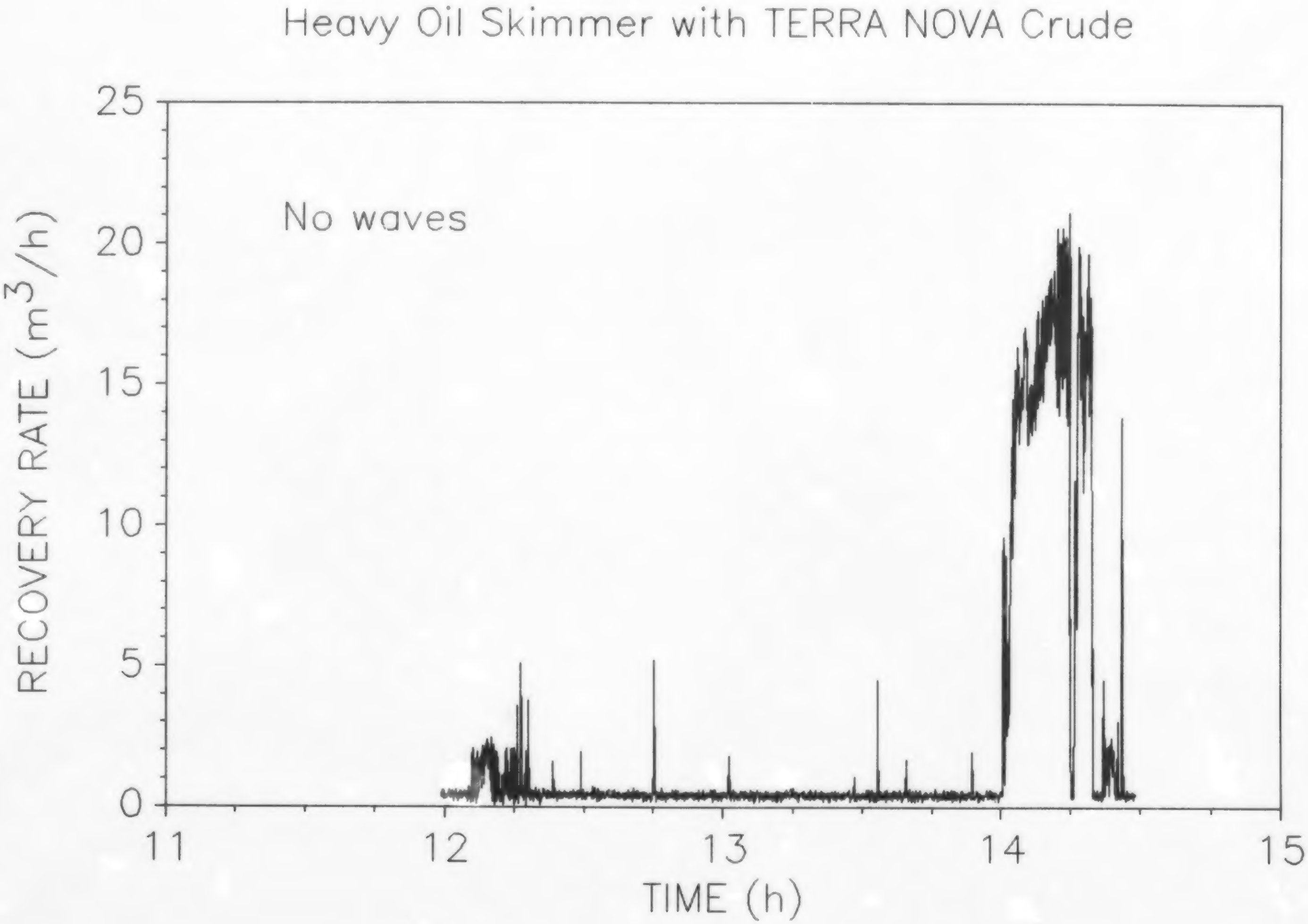
Walosep with IPL
RECOVERY RATE (m3/h)
0
10
20
30
40
50
9
10
11
12
13
14
15
TIME (h)
Start wave
Stop wave

CHRONOLOGY — TEST #9

SKIMMER: WALOSEP W-2
OIL: IPL Sweet

DATE: 06/10/88
WATER T (°C) = 15
OIL T (°C) = 10.5
OIL VOL. (m³) = 2.6

APPROXIMATE TIME OF DAY	WAVES H (m)	T (s)	L (m)	SKIMMER ROTOR	WEIR	PUMP	COMMENTS
09:17	0	0	0	12-13	– 5 cm	3½	start
09:22	0	0	0	"	"	"	
09:31	0	0	0	"	"	"	
09:38	0	0	0	"	"	"	
09:51	0	0	0	"	"	"	
10:07	0	0	0	"	"	3½ +	— try increasing pump speed, power pack not enough — reduce pump to 3½
10:45	0	0	0	"	"	3½	
11:05	—	—	—	"	"	"	waves on
11:08	0.4	4.3	20	"	"	"	
11:19	0.3	4.2	20	"	"	"	
11:24	0.65	—	—	"	"	"	
11:33	0.8	—	—	"	"	"	
11:38	0.63	—	—	"	"	"	
11:58	0.4	—	—	"	"	"	
12:02	0.42	4	20	"	"	"	
12:19	0.46	4	20	"	"	"	
12:30	0.46	4	20	"	"	"	
12:40	0.41	4	20	"	"	"	
12:55	0.37	4	—	"	"	"	
12:59	0.37	4	—	0	"	0	shut down for Elastol add'n
14:00	0.46	4	—	—	"	—	restart skimmer
14:03	0.5	—	—	12-13 rpm	"	3½	
14:07	0.5	3.9	—	"	"	"	
14:12	0.51	—	—	12-13	– 5 cm	2¾	reduce pump speed
14:20	0.8	4	—	"	"	"	stop waves, pump to slops



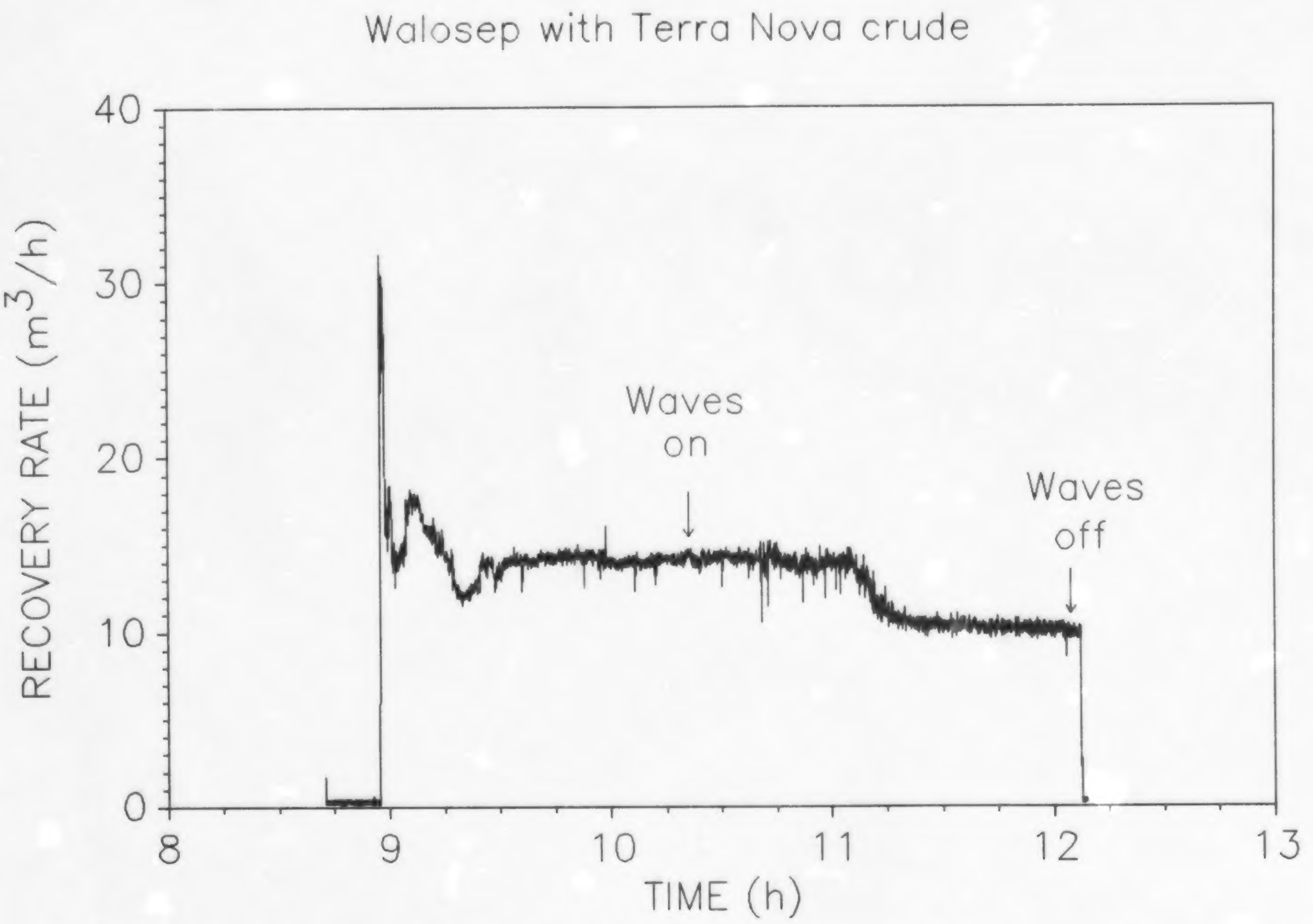
Heavy Oil Skimmer with TERRA NOVA Crude

CHRONOLOGY — TEST #10

SKIMMER: H.O.S.
OIL: Terra Nova

DATE: 07/10/88
WATER T (°C) = 15
OIL T (°C) = 35.6
OIL VOL. (m³) = 3.52

APPROXIMATE TIME OF DAY	WAVES H (m)	T (s)	L (m)	SKIMMER DRUM	WEIR	PUMP	COMMENTS
10:51	0	0	0	10 rpm + ve	N/A	10 bar	start
10:52	0	0	0	—		—	stop — no recovery noted — oil running around scrapers instead of into sump
11:20	—	—	—	0		0	waves on to cool oil $T_0 = 28°C$
11:45	—	—	—	0		0	waves off $T_0 = 19°C$
11:58	0	0	0	15 rpm + ve		30	restarted test — some recovery noted
12:15	0	0	0	—		—	stop test
12:22	—	—	—	0		0	restart waves to weather oil
12:40	—	—	—	0		0	waves off — boom leak
12:45	0	0	0	13 rpm + ve		20	restart skimmer
13:00	0	0	0	0		0	stop
13:45	0	0	0	0		0	add Elastol
13:59	0	0	0	13 rpm + ve		30	restart skimmer
14:04	0	0	0	"		"	
14:13	0	0	0	13 rpm − ve		"	reverse drum rot'n.
14:15	0	0	0	13 rpm + ve		"	rereverse drum rot'n.
14:20	0	0	0	0		0	stop

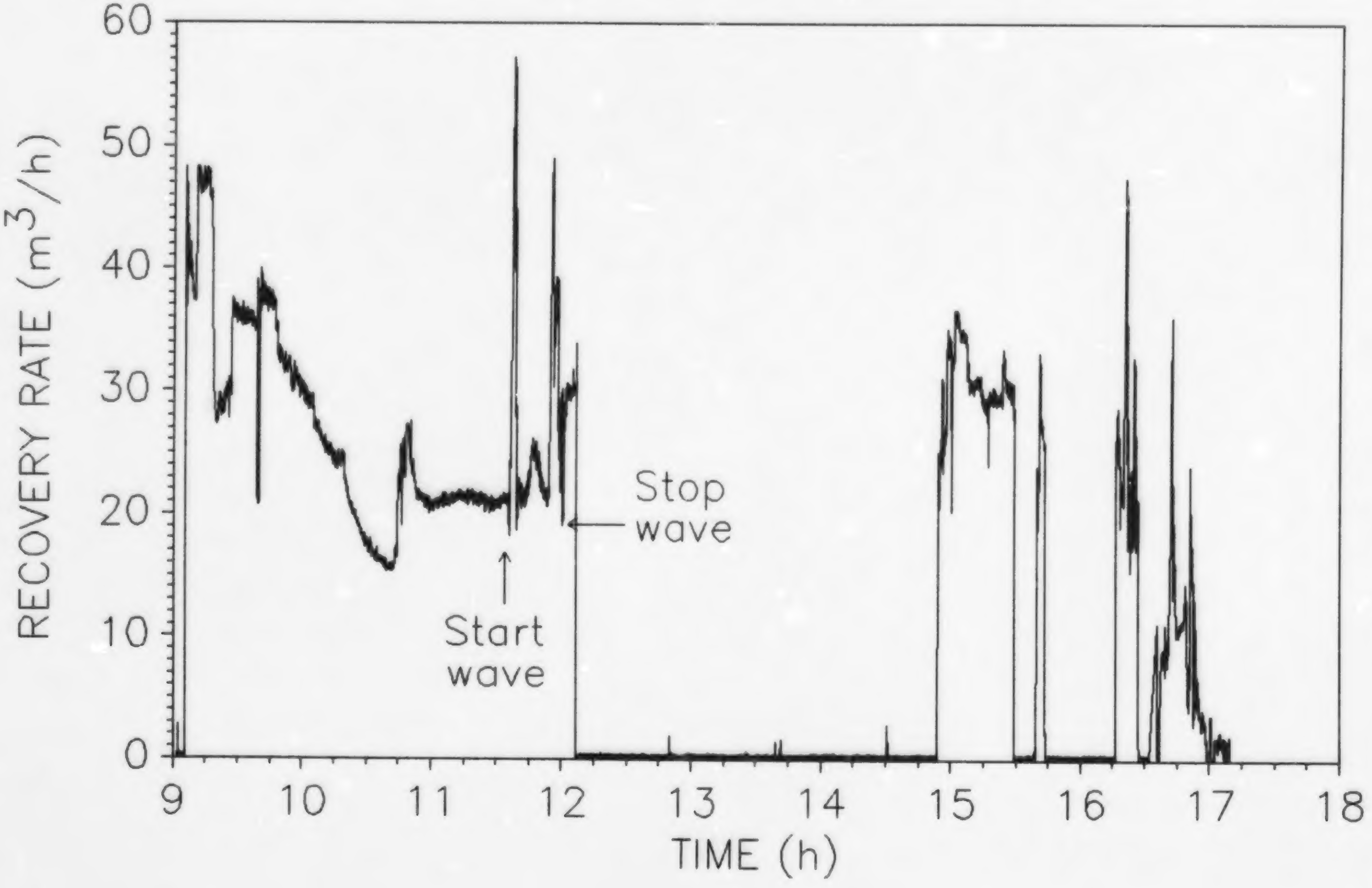

Walosep with Terra Nova crude
RECOVERY RATE (m3/h)
0
10
20
30
40
TIME (h)
8
9
10
11
12
13
Waves on
Waves off

CHRONOLOGY — TEST #11

SKIMMER: WALOSEP W-2
OIL: Terra Nova

DATE: 08/10/88
WATER T (°C) = 15
AIR T (°C) = 5
OIL VOL. (m^3) = 3.3
(added day before)

APPROXIMATE TIME OF DAY	WAVES			SKIMMER			COMMENTS
	H (m)	T (s)	L (m)	ROTOR	WEIR	PUMP	
08:55	0	0	0	12-13 rpm	– 5 cm	0	start
08:58	0	0	0	"	"	2½	due to oil visc., this is max. setting with GT-185 power pack
09:00	0	0	0	"	"	"	oil behaving like "floes" on surface — fluid beneath
09:03	0	0	0	"	"	"	oil flowing from spill plate to skimmer — repositic
09:05	0	0	0	"	"	"	
09:10	0	0	0	"	"	"	
09:32	0	0	0	"	"	"	
09:50	0	0	0	"	"	"	
10:15	0	0	0	"	"	"	sun out — warming surface oil
10:20	—	—	—	"	"	"	waves on
10:25	0.35	4.26	20	"	"	"	
10:39	0.71	4.1	20	"	"	"	
10:55	0.5	4.1	—	"	"	"	
11:10	0.46	4.06	—	"	"	"	
11:20	0.42	4.1		"	"	"	
11:30				"	"	"	time differential
11:55	0.42	4.1		"	"	"	
12:03	0	0	0	"	"	"	waves off
12:07	0	0	0	"	"	0	pump off
12:11	0	0	0	0	"	0	stop test, start calibration



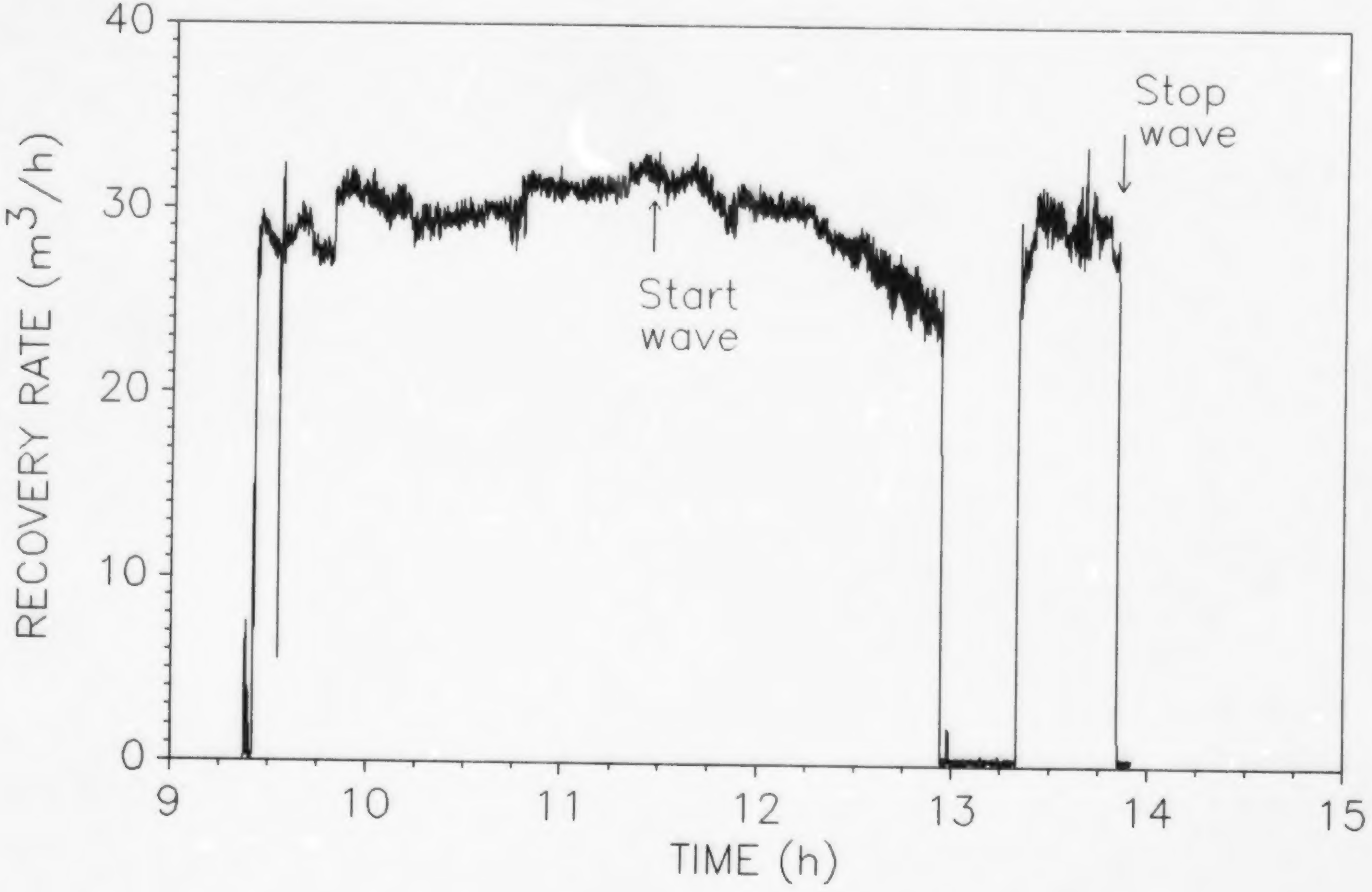
ACW–400 with Terra Nova Crude

CHRONOLOGY — TEST #12

SKIMMER: FRAMO ACW-400
OIL: Terra Nova

DATE: 11/10/88
WATER T (°C) = 13
AIR T (°C) = 5
OIL VOL. (m^3) = 3.38
(added day before)

APPROXIMATE TIME OF DAY	WAVES			SKIMMER			COMMENTS
	H (m)	T (s)	L (m)	DISC	WEIR	PUMP	
09:06	0	0	0	10.4 rpm	up	40-50 bar	start
09:09	0	0	0	"	"	40	skimmer emulsifys oil
09:19	0	0	0	"	up more	"	raise skimmer to check weir
09:22	0	0	0	"	"	"	weir seems to have been drawing water before 09:19
09:30	0	0	0	14.3	"	"	increase disc speed
09:50	0	0	0	16.8	"	"	increase disc speed
10:08	0	0	0	"	"	50	increase pump pressure
10:18	0	0	0	"	"	60	increase pump pressure
10:20	0	0	0	"	– 5 cm	"	lower weir
10:24	0	0	0	"	"	"	
10:30	0	0	0	"	"	"	
10:45	0	0	0	—	—	—	adjusting weir down
10:53	0	0	0	"	full down	65	increase pump pressure
11:35	0	0	0	"	"	"	
11:36	—	—	—	"	"	"	waves on
11:38	0.3	4.2	20	"	"	"	
11:45	0.3	4.2	20	"	up	"	weir up, skimmer pumping oil under of booms
11:50	0.35	3.9	20	—	"	"	reduce disc speed
11:55	0.48	3.8	20	14.3	"	"	skimmer pumping excessive oil under booms — shut off waves
12:00	0.75						
12:07	0	0	0	0	0	0	shut down skimmer while recovering escaped oil
14:55	0	0	0	10 rpm	up	50-55	restart
15:00	0	0	0	"	"	50-60	
15:15	0	0	0	14.3	"	60	increase pump
15:22	0	0	0	15	"	"	increase disc
15:25	0	0	0	"	– 5 cm	"	lower weir
15:30	0	0	0	0	0	0	end test



GT–185 with Terra Nova Crude

CHRONOLOGY — TEST #13

SKIMMER: GT-185
OIL: Terra Nova

DATE: 12/10/88
WATER T (°C) = 12
AIR T (°C) = 0
OIL VOL. (m³) = 3.33
(added day before)

APPROXIMATE TIME OF DAY	WAVES			SKIMMER			COMMENTS
	H (m)	T (s)	L (m)	DISC	WEIR	PUMP	
09:30	0	0	0	N/A	– 3 cm	2½ @ 1000 psi @ 2500	start oil "floes"
09:42	0	0	0		"	6½	
09:54	0	0	0		"	800 psi	
10:06	0	0	0		"	850 psi	oil fluidizing
10:25	0	0	0		"	"	
10:49	0	0	0		"	750 psi	
11:22	—	—	—		"	"	waves on
11:27	0.25	4.2	20		"	850 psi	
11:34	0.3	4.2	20		"	"	some emulsion from skimmer
11:39	0.37	4.2	20		"	"	
11:43	0.45	—	—		"	"	
11:47	0.61	—	—		"	"	
11:52	0.78	—	20		"	"	
11:58	0.75	—	—		"	900 psi @ 2600 rpm	
12:08	0.61	—	—		"	"	
12:23	0.48	4.2	20		"	"	
12:41	0.40	4.2	20		"	"	
12:58	0.38	4.2	20		"	"	
13:00	—	—	—		0	0	raise skimmer for Elastol
13:23	—	—	—		—	—	restart
13:26	0.4	—	—		– 3 cm	900 psi @ 2600	
13:36	0.38	—	—		"	"	
13:45	0.4	—	—		"	"	waves off
13:50	0	0	0		"	"	
13:55	0	0	0		0	0	end test